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Figure 17. Montemalaga Elementary School short term radon detector results for the 6/6 – 6/8/03 period. The

AN ANALYSIS OF RESIDENTIAL RADON MEASUREMENTS IN KANSAS UTILIZING GRAPHICAL INFORMATION SYSTEM (GIS) TOOLS

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Abstract

Beginning January 1, 1987, the state of Kansas began collecting and recording data from residential radon tests. This data was collected based entirely upon voluntary home testing, performed by 1) the home owner (using a store-purchased radon test kit), 2) a professional radon testing laboratory or 3) by technicians from the Kansas Department of Health and Environment (KDHE) state laboratory. The majority of test results are from tests conducted by homeowners. The radon database was analyzed using Arc Info 8.2. Three primary graphical information system (GIS) analyses were performed: 1) a comparison of the Kansas database to the Environmental Protection Agency (EPA)/ Unites States Geographical Service (USGS) radon threat map for Kansas, 2) a data density analysis of statewide testing patterns and 3) an analysis of average radon values across clustered zip code districts in Sedgwick County, Shawnee County and the Kansas City metropolitan area (including Johnson, Wyandotte, Leavenworth and Douglas Counties). Comparison of the Kansas radon database to the EPA/USGS threat assessment map showed similar but not identical trends. The data density analysis identified the zip code districts for which no test results had been collected and identified the areas of Kansas, which have undergone the most extensive radon testing. The average radon variability analysis

indicates that zip codes that have large n-values of radon tests show a fair amount of congruity when clustered in defined geographical regions.

Introduction

Among a number of indoor air quality (IAQ) issues, exposure to elevated levels of indoor radon gas poses a significant health risk, while also offering to be one of the simplest indoor environmental hazards to remediate. Radiation released by the radioactive decay of radon can cause lung tissue damage, thereby increasing the risk of an individual developing lung cancer. However, simple methods exist that reliably reduce the amount of radon gas in a home, thereby reducing the risk.

Appendix B of the Technical Support Document for the 1992 Citizens Guide to Radon (EPA 1992b) provides a comprehensive background on radon. Radon is a chemically inert, naturally-occurring, radioactive gas. The two primary sources of radon are the radioactive elements thorium and uranium, both of which undergo radioactive decay into radium. Radium undergoes radioactive decay into radon gas. Radioactivity is measured in curies, where 1 curie equals 37 billion elemental disintegrations per second. Radon gas is measured in picocuries (pCi/L), or one-trillionth of a curie. The danger presented by radon is primarily related to its radioactive decay products. The radon decay products have very short half-lives (less than 30 minutes) and are the source for most of the radioactivity caused by radon. These decay products are polonium-218, lead-214, bismuth-214, and polonium-214; polonium-218 and polonium-214 pose the greatest health risk as they both emit an alpha particle during their decay process. The alpha particle is the particle that causes damage to lung tissue.

Radon is found virtually everywhere as its predecessors' (uranium and radium) are found in all rock and soil types (EPA 1992a). Outdoor air concentrations of radon are generally less than 1.0 pCi/L but have been measured as high as 1.11 pCi/L. Indoor radon gas concentrations can vary from as little as 0.5 pCi/L to as high as 2000 pCi/L. The EPA has set an action level of 4.0 pCi/L indoor radon; levels equal to or greater than this level are recommended to be lowered. The National Residential Radon Survey indicates that 1 in 15 homes (or approximately 6%) will have radon gas levels above 4.0 pCi/L. Iowa has the highest risk of elevated indoor radon levels at 7 in 10 homes (approximately 77%). Hawaii has the lowest exhibited risk at less than 1 in 100 homes (less than 1%). The state of Kansas has a risk factor of approximately 1 in 4 homes (25%) that will exhibit elevated indoor radon (EPA 1993a).

Based on numerous studies of lung cancer in radon-exposed underground miners, radon has been classified as a human carcinogen (IARC 1988). As such radon is the second leading cause of lung cancer death behind tobacco smoking, according to the United States Surgeon General's Office (EPA 1993c). The current official estimate of lung cancer deaths attributed to radon is 15,000-22,000 (EPA 2002). Epidemiological estimates however raise that number and might actually exceed 38,000 lung cancer deaths per year (Field, Smith, Steck and Lynch 2002).

The most current federal review of radon risk potential was the sixth Committee on Biological Effects of Ionizing Radiations (BEIR VI) (NRC 1999). In order to determine the mechanistic effect of radon carcinogenesis, a review of the available molecular studies indicated that a single alpha particle impact on lung epithelial tissue can cause significant genomic damage in cells that are not killed by the incurred damage. This effect led to the adoption of a linear relationship between alpha particle dose and cancer risk. Alpha particles which are generated by airborne radon decay (and subsequently inhaled) and by radon decay within the lungs are used to determine overall equivalent dose (Kendall and Smith 2002). Using the EPA's four risk types (cancer, non-cancer health effects, ecologic effects and welfare effects) for 31 environmental problems, radon was therefore ranked as a high cancer and non-cancer health risk and placed among 12 assessed risks including indoor air pollutants other than radon, accidental releases of toxic materials and exposure to consumer products (Johnson 2000)

The EPA measures progress with radon issues across four major categories; 1) awareness of the general public about radon, 2) the number of homes tested for radon contamination, 3) the number of homes that exhibit elevated levels of radon that have been mitigated and 4) the number of new homes built with radon resistant new construction (RRNC) (Gregory and Jalbert 2002). A study of surveys conducted by the EPA between 1993 and 1999 provided baseline successes across those four categories. By 1999, 68% of survey respondents were aware of radon and aware of the primary health threat, that is the increased risk of lung cancer. Testing of homes for radon hit a peak number of tests in 1999 of approximately 1.5 million homes. Since the mid-1980's, it is estimated that 18 million homes total have been tested. This number is difficult to truly estimate as the EPA does not require that tests be reported either to it or to the relevant state health or environmental offices. Mitigation of homes has steadily increased since 1993, reaching a peak of more than 50,000 homes in 1999. It is estimated that 500,000 homes have been mitigated since the mid-1980. The last category, homes built with RRNC techniques, has remained relatively level since 1990, with an estimated 1.8 million homes having been built with RRNC systems since the early 1990's.

The primary source of exposure to radon for the general public is the home (Field 2002). The major sources of indoor radon are 1) soil gas emanations from soils and rocks, 2) release of radon from water systems, 3) building materials and 4) outdoor air. Soil gas is the predominant source. Four primary testing methods exist for measuring indoor radon gas concentrations; 1) activated charcoal adsorption, 2) alpha track detectors, 3) electret ion chamber detectors and 4) continuous radon monitoring devices. These methods are designed to perform either short-term radon tests (tests lasting less than 90 days), long-term radon tests (tests lasting longer than 90 days) or both. Activated charcoal tests are typically deployed for 2-7 days, and allow continual adsorption and desorption of radon across the exposure time. This device yields a single average radon value for the exposure period. Alpha track detectors are designed for long-term deployments and function by measuring the number of alpha particle strikes on a plastic strip or film across the exposure period. This device also yields a single average radon concentration. Electret ion chamber devices can be deployed for either short-term or long-term periods. Ion chamber radon measurements are obtained by measuring the difference in ion charge across a Teflon plate, caused by ionizing radiation released by radon as it decays. Electret devices yield a single average concentration across the deployment period. Continuous radon monitors record radon levels every hour and provide a point-by-point graph of radon levels as well as generating an average value for the testing period.

In order to assess the national potential for radon generation and indoor radon elevation potential the EPA and the United States Geological Service (USGS) performed a national survey of all 50 states between 1987-1989 (EPA 1993a). This survey was designed to set a threat potential for all 3141 counties in the United States (EPA 1993b). Three threat potential zones were used to describe each county's radon potential; 1) Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L, 2) Zone 2 counties have a predicted average indoor radon screening level of 2.0 to 4.0 pCi/L and 3) Zone 3 counties have a predicted average indoor radon screening level of less than 2.0 pCi/L. Graphical representations of the country and of each state were generated once the county threat potentials were designated. Figure 1 represents the United States as a whole and Figure 2 represents the state of Kansas.

It needs to be noted that these maps are not designed to predict the radon level of individual homes (EPA 1993a). The county designations are designed to predict regional radon potential. Information used to develop the county designations included indoor radon measurements, geology, aerial radioactivity, soil permeability and foundation type (EPA 1993b). It is possible to have elevated indoor radon even in Zone 2 and Zone 3 counties. Even with Hawaii's low potential, a home has been found to have indoor radon exceeding 80 pCi/L, more than 20 times the EPA recommended action level of 4.0 pCi/L.

Additional GIS analysis for radon potential by the states has been haphazard. Ohio and Pennsylvania have created limited, single-county GIS databases designed primarily to describe geographic patterns of indoor radon (Harnapp, Dollwet and Rong 1997; Geiger and Barnes 1994). Connecticut developed a state-wide GIS database, using 5000 indoor radon results and 700 well results (Siniscalchi, Tibbetts, Beakes, Soto, Thomas-Margaret, McHone and Rydell, 1996). One of the most ambitious radon GIS project is international. Sweden has attempted to develop a GIS model for the country based on the national census register and standard global positioning system (GPS) technology to identify the potential radon exposure for most of the country's population (Kohli, Sahlen, Lofman, Siverturn, Foldevi, Trell and Wigertz 1997).

The purpose of the current study is to expand on the geographical analysis of radon potential for Kansas. The study will attempt to do three things. The first is to compare current state indoor radon testing data with the original EPA/USGS county zone designations. This analysis is expected to conform in nature to the original graphical representation for Kansas. The second is to identify regions of Kansas that show limited or zero indoor radon testing. The purpose of this analysis is to identify areas of the state, which have been underserved by state and federal radon programs. The third is to compare regional clusters with high numbers of radon tests for internal consistency of average radon results. This analysis is expected to show that clustered regions with high n-values of radon tests will yield similar average radon results, which would provide better definition of radon potential in such regions.

MATERIALS AND METHODS

Participants

The participating homes which have had radon gas tests performed and that have been recorded in the Kansas Radon database are collected from one of three primary sources. One source is the voluntary testing of homes by homeowners that have purchased state-subsidized test kits. Test kits are distributed throughout the state by the Kansas State University Research and Extension Service and by a limited number of county health departments. A second source is tests performed by professional radon testing labs, most notably RTCA and Alpha Energy Labs, whose services are retained by the homeowner. Results from these companies are turned over to the Kansas Department of Health and Environment (KDHE). The third primary source of residential test results is the KDHE laboratory from tests performed as part of whole-home inspections.

It should be noted that the database does not receive the results of radon tests performed by home inspectors as part of a real estate transaction unless those tests are performed using equipment from testing labs, which submit their results to KDHE. This omission is important as real estate-derived radon tests generate the second highest number of tests performed each year behind the state radon program distribution system.

Apparatus

A Dell Dimension desktop computer, utilizing the Microsoft Windows 2000 operating system was used to perform the analyses below. The Kansas Radon Program database is maintained in Microsoft Access format. The graphical information system (GIS) used to analyze the database is ESRI Arc Info 8.2. Microsoft Word was used to write the report contained herein.

Procedure

The Kansas Radon Program database is organized by the statewide zip code system. Radon test results generated by the sources described above are reported to the state with the origin of the test being identified by its zip code. In all test result cases, the zip code and the radon value are entered. When available, additional information, such as the type of test equipment and the location of the test, is also entered. Data is available starting from January 1, 1987 and updated through December 1, 2002. A total of 22,148 test results were available for analysis.

Arc Info 8.2 is capable of integrating information maintained in Microsoft Access format. In order to collate the database into a format suitable for import into Arc Info 8.2, a summary file of the Kansas Radon Program database was generated using Microsoft Access. The summary file contained entries for 1) each zip code for which radon gas data was available, 2) the average radon gas level of the available data for each zip code, 3) the minimum radon value for each zip code, 4) the maximum radon value for each zip code and 5) the total number of test results for each zip code. It should be noted that not all Kansas zip codes have data associated with them. This situation is caused by the volunteer nature of residential radon testing in Kansas and is examined in detail below.

The database summary file was imported into Arc Info 8.2 using a "join" procedure. This procedure appends a data file to an Arc Info 8.2 shape file using a data element common to the two files; in this case the common element was the zip code numbers for Kansas. The shape file used for this analysis was the zip code shape file delineating each Kansas zip code district from the ESRI data CD-ROM for the western United States (as distributed by ESRI in Arc View 8.0).

The joined data file provided a graphical representation of Kansas as delineated by each zip code district's boundaries. This representation was used to perform a number of analyses, using the tools available in Arc Info 8.2. The first analysis generated a map of Kansas using the EPA/USGS three radon risk zones plus one zone used to indicate zip code districts for which no test results are available. The second analysis generated a data density plot for all zip code districts for which data was available, as well as creating a highlight map of Kansas identifying zip code districts for which no data is currently available. The third analysis generated a map identifying specific counts of radon tests per zip code. This map was used to identify three areas in Kansas with zip code clusters with relatively high number of radon samples (greater than 25 samples in a zip code district); Shawnee County, Sedgwick County and the Kansas City Metropolitan area (including Wyandotte County, Leavenworth County, Johnson County and Douglas County).

RESULTS

Analysis 1: EPA/ Kansas Database Threat Comparison

The first GIS analysis was a comparison of the original EPA/USGS threat designation to the results of the ongoing data compilation in Kansas. The EPA/USGS analysis performed across the country during the 1987-1989 time period set three classes of radon threat, broken out by each county within a state. Zone (1) counties have the highest potential for elevated indoor radon levels of 4.0 pCi/L or higher. Zone (2) counties average indoor radon levels of 2.0 to 4.0 pCi/L concentrations. Zone (3) counties expect average indoor radon levels of less than 2.0 pCi/L concentrations. Kansas exhibits a majority of counties as Zone (1), with the southern and eastern counties ranking as Zone (2) (see Figure 3).

A comparison of the data collected in the Kansas database, using the same zone criteria as EPA/USGS, identifies a similar trend (see Figure 4). While the individual zip codes do not necessarily exhibit the same average indoor radon concentrations as expected by the EPA/USGS county analysis, the identified trends of higher average indoor radon levels in the northwest and central portions of Kansas and lower average indoor radon levels in the southeast region of the state are confirmed.

Analysis 2: Data Density Analysis of Radon Testing in Kansas

As noted in Figure 2, the database is lacking in data for a number of zip code districts in Kansas (see Figure 5). This lack of data is a result of the voluntary nature of residential radon testing in Kansas. An analysis of testing density indicates that the zip codes with the highest number of recorded test results occur in areas with the highest population densities (see Figure 6). The map clearly indicates that the metropolitan areas of Kansas City, Topeka and Wichita have recorded the greatest number of radon tests. The regions surrounding Hutchinson, Manhattan, and Salina exhibit the next tier of testing densities.

Analysis 3: Radon Variability in Zip Code Clusters with Large N Values

A direct examination of total number of radon tests in Kansas revealed that the Kansas City, Topeka and Wichita areas showed the highest densities of recorded tests. These three areas exhibited clusters of zip codes with relatively high n-values, equal to or exceeding 25 radon tests (see Figure 7). Shawnee County and the Topeka area have the fewest number of high-n zip codes with a cluster of 18 districts. Sedgwick County and the Wichita area exhibited 20 high-n districts. The Kansas City Metropolitan area, including Johnson County, Wyandotte County, Leavenworth County and Douglas County, exhibited 42 zip code districts.

Each of these three regions was examined for variability of average radon values across the zip code clusters. For each region, the results of all the zip code radon averages were graphed. The region-wide analysis was followed by an analysis of zip code districts with 25 or more radon test results. The 25 or more analysis was followed by an analysis of zip code districts with 50 or more radon test results. The 50 or more analysis was followed by an analysis of zip code districts with 100 or more radon test results. Each graph shows the complete range of average radon values for the zip code districts involved. The dotted blue lines delineate one standard deviation in difference between the average values for each chart. The solid red line indicates the EPA's recommended action level of 4.0 pCi/L indoor radon concentrations. The error bars for each individual zip code denote standard calculated error. The inset pictorial of the region being examined is colored as to the average radon value for each zip code, following the EPA's radon zones described above.

1) Sedgwick County

The variability of average radon values shows a decreasing trend in Sedgwick County based on increasing n-values across zip code districts. Total n-value of radon tests for Sedgwick County is listed in Figure 8. As demonstrated in the graph of Figure 9, Sedgwick County as a whole exhibits a standard deviation range of approximately 1.5 pCi/L to 5.0 pCi/L average indoor radon concentration. As n-values for the zip code districts increase however, the variability decreases. Accounting for zip code districts with an n-value of 25 or greater, the standard deviation reduces to 2.5 pCi/L to 4.0 pCi/L (see Figure 10). In zip code districts with n-values of 50 or greater, the standard deviation range is again 2.5 pCi/L to 4.0 pCi/L (see Figurel 1). In zip code ranges with n-values of 100 or greater, the standard deviation reduces to 2.5 pCi/L to 3.7 pCi/L (see Figure 12).

2) Shawnee County

The variability of average radon values shows a decreasing trend in Shawnee County based on increasing n-values across zip code districts. Total n-value of radon tests for Shawnee County is listed in Figure 13. As demonstrated in the graph of Figure 14, Shawnee County as a whole exhibits a standard deviation range of approximately 2.7 pCi/L to 5.3 pCi/L. As n-values for the zip code districts increase however, the variability decreases. Accounting for zip code districts with an n-value of 25 or greater, the standard deviation reduces to 3.2 pCi/L to 5.5 pCi/L (see Figure 15). In zip code districts with n-values of 50 or greater, the standard deviation range is again 3.2 pCi/L to 5.5 pCi/L (see Figure 16). In zip code ranges with n-values of 100 or greater, the standard deviation reduces to 3.7 pCi/L to 5.2 pCi/L (see Figure 17).

3) Kansas City Metropolitan Area

The variability of average radon values shows a stable trend in the Kansas City metropolitan region, based on increasing n-values across zip code districts. Total n-value of radon tests for the Kansas City region is listed in Figure 18. . As demonstrated in the graph of Figure 19, Shawnee County as a whole exhibits a standard deviation range of approximately 3.2 pCi/L to 5.5 pCi/L. Accounting for zip code districts with an n-value of 25 or greater, the standard deviation reduces to 3.7 pCi/L to 5.7 pCi/L (see Figure 20). In zip code districts with n-values of 50 or greater, the standard deviation range is again 3.7 pCi/L to 5.5 pCi/L (see Figure 21). In zip code ranges with n-values of 100 or greater, the standard deviation reduces to 3.9 pCi/L to 5.7 pCi/L (see Figure 22).

DISCUSSION

Geographical analysis of observed Kansas's indoor radon test results provides information valuable to the state radon control program. The data reaffirms the original EPA/USGS radon potential map. The analysis of the test count distribution clearly identifies regions of Kansas that require greater testing attention. The data also indicates that regions with high numbers of test results generate coherent and consistent average radon values.

It should be restated that GIS analysis of radon results by region are not designed to predict the indoor radon level of any given house. That having been said, the current study has provided the Kansas Radon Program with several pieces of useful information. First, the study reiterated the state-wide potential for radon using considerably more indoor radon data than the 1987-88 survey, which included 2009 household samples (EPA 1993a). The current Kansas database contains in excess of 22,000 indoor radon samples as of December 2002. A comparison of the EPA radon potential map for Kansas (Figure 3) to a map using current results and identical range categories (Figure 4) indicates a strong pattern similarity. Differences in boundaries between the maps are due to the use of zip code borders in Figure 4 versus county borders in Figure 3. The primary value in this result is the additional confidence the current results give the EPA zone designations. One of the EPA's primary goals in relation to radon is to encourage the use of radon resistant new construction (RRNC) in new single and two-family housing in Zone 1 counties. The current study provides additional information when working with state and local planning officials in relation to radon.

Second, the study clearly identifies regions of Kansas for which there are few to zero radon test results available (Figure 5). Taking into account the low population density of many rural Kansas counties, this information indicates areas that may be being underserved by state and federal radon programs (Figure 6). Given the relatively high chance (25%) of any given home in Kansas to exhibit elevated radon, the identification of these areas offer substantial information in relation to where to focus available resources. In terms of the Kansas Radon Program, this equates both to educational opportunities and to the distribution of available grant funds that can be used to subsidize non-commercial residential testing.

Third, the study indicates that where substantial radon testing has occurred, that data can be used to create maps for Kansas's counties with greater apparent resolution than the standard EPA Kansas map. This resolution is possible because of the ability to separate data into smaller regions (limited to zip code by the nature of the database organization). As such, the results of the current study indicate that when zip codes accumulate relatively high n-values of test results the resulting map of averages across those zip codes exhibit fairly low variation. The reduced variation further enhances the ability of the Kansas Radon Program to isolate regions of particularly high radon activity. The study also sets an obvious goal of at least 50 test results per zip code, with an ideal zip code sample being greater than 100 tests. Examining the results of the most heavily sampled area (the Kansas City Metropolitan area), the variation between the 50+ (Figure 21) and 100+ (Figure 22) n-value zip codes is relatively minor.

The current study shows the value of adopting GIS techniques to study state-wide trends in radon potential. These trends provide insight that can be used to further the debate on the use of RRNC building systems in regions with high observed radon potential. The trends offer information on potentially underserved regions of the state in regards to radon education and testing. And the trends allow state and local personnel to benefit from regional maps with greater resolution than those available from the EPA/USGS study. As ongoing data is included, the database will become ever more useful. The identification of regions with little to no testing can be examined specifically and those discrepancies can be reduced.

Implications for state and local planning are dependent upon governmental official's abilities to disseminate and interpret the data presented. Given the importance of radon from a health risk assessment, it is hoped that this study, along with additional and ongoing similar research, will be of use in setting realistic governmental policy for adequate control of radon as an IAQ issue.

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TABLES AND GRAPHS

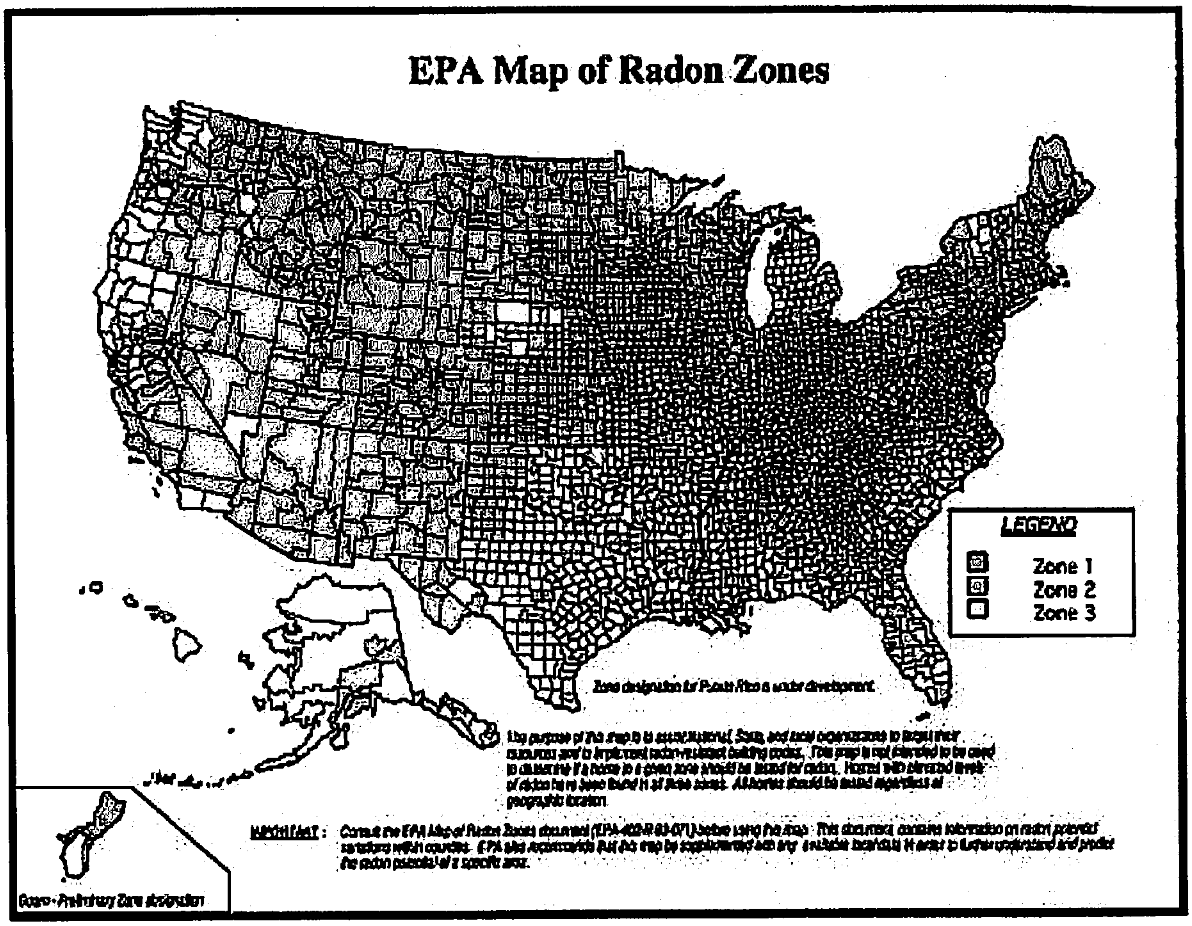


Figure 1. The EPA/USGS county designation map of the United States. Zone 1 counties are colored in red. Zone 2 counties are colored in orange. Zone 3 counties are colored in yellow.

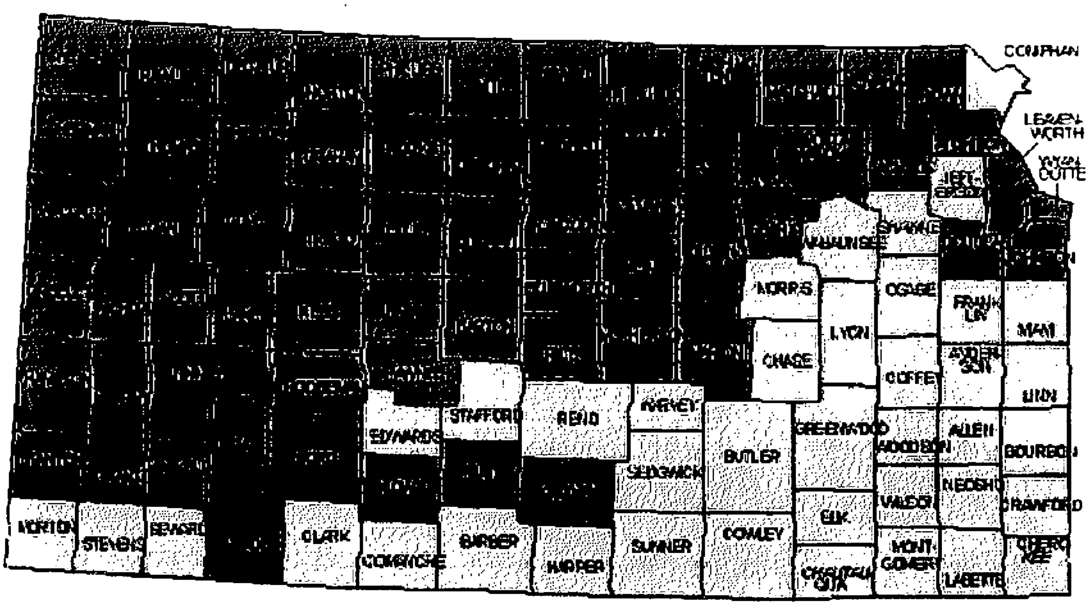


Figure 2. The EPA/USGS Zone designation listed for Kansas's counties. The southeast area of the state is classified Zone 2 while the northwest and central portions of the state are classified Zone 1.

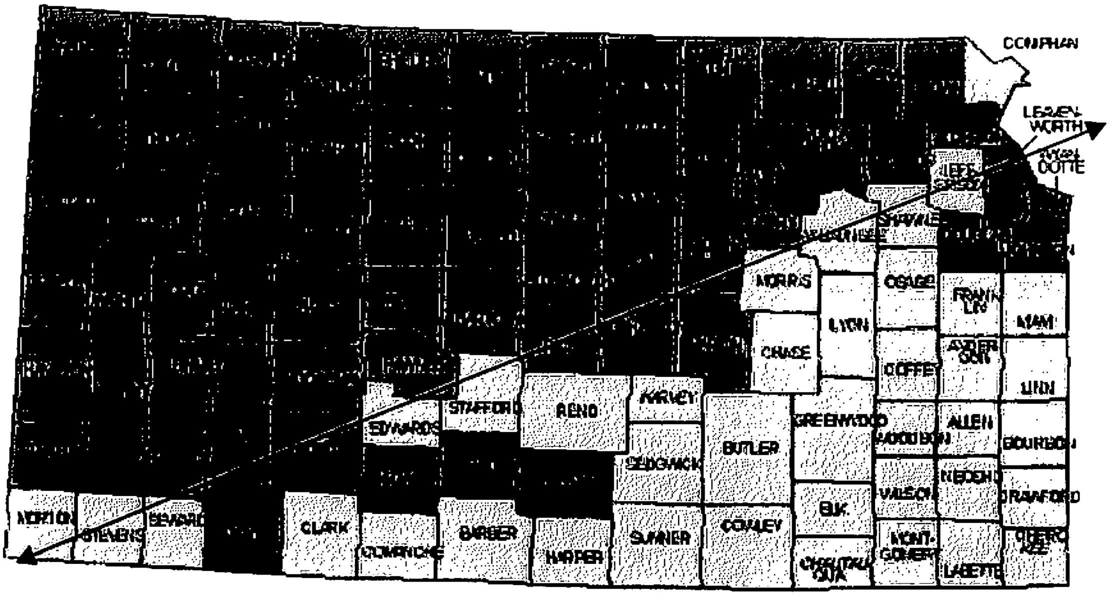


Figure 3. The EPA/USGS Zone designation listed for Kansas's counties. The southeast area of the state is classified Zone (2) while the northwest and central portions of the state are classified Zone (1).

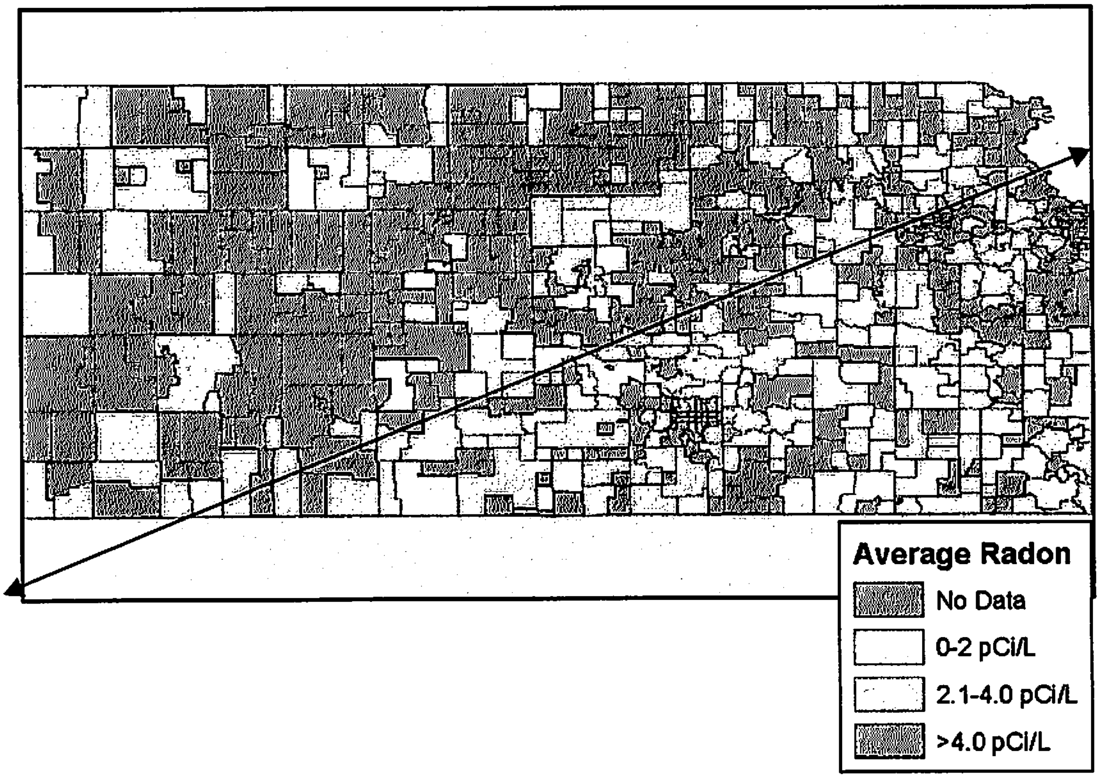


Figure 4. A map of Kansas zip code districts. Each zip code district is ranked as per the EPA/USGS zone categories, excepting zip codes for which no data has been collected.

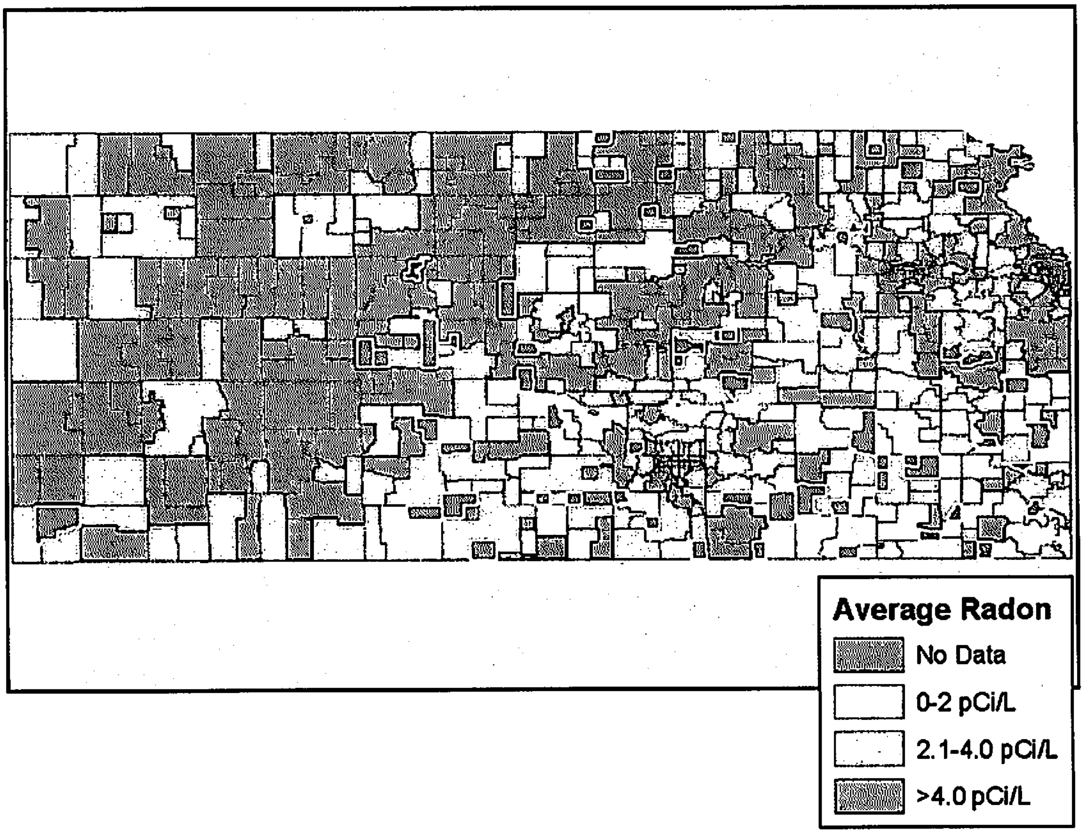


Figure 5. Zip code districts that have not recorded any radon test reports are highlighted in blue.

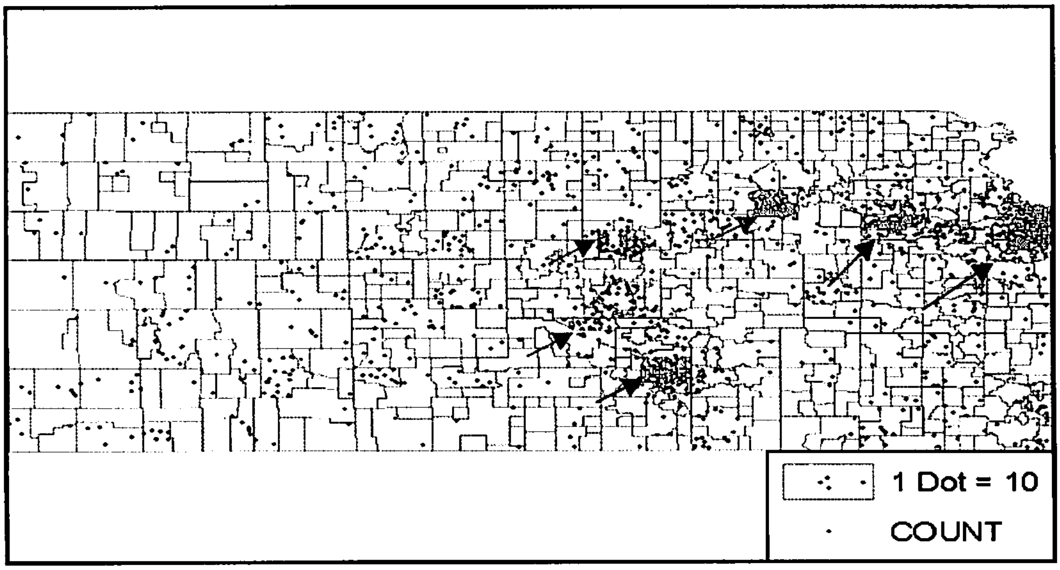


Figure 6. This map is a data density plot of the total number of radon test results taken in Kansas from January 1, 1987 through December 1, 2002, or a grand total of 22,148 tests.

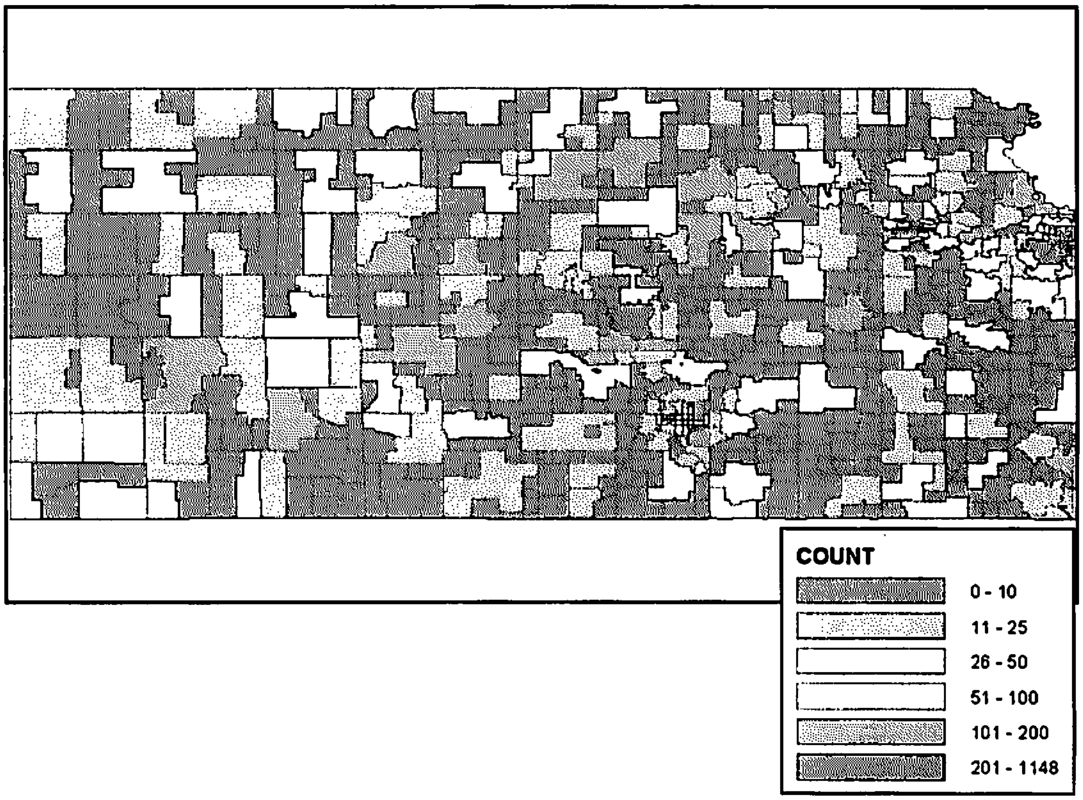


Figure 7. Kansas's zip code districts examined by total number of recorded radon tests.

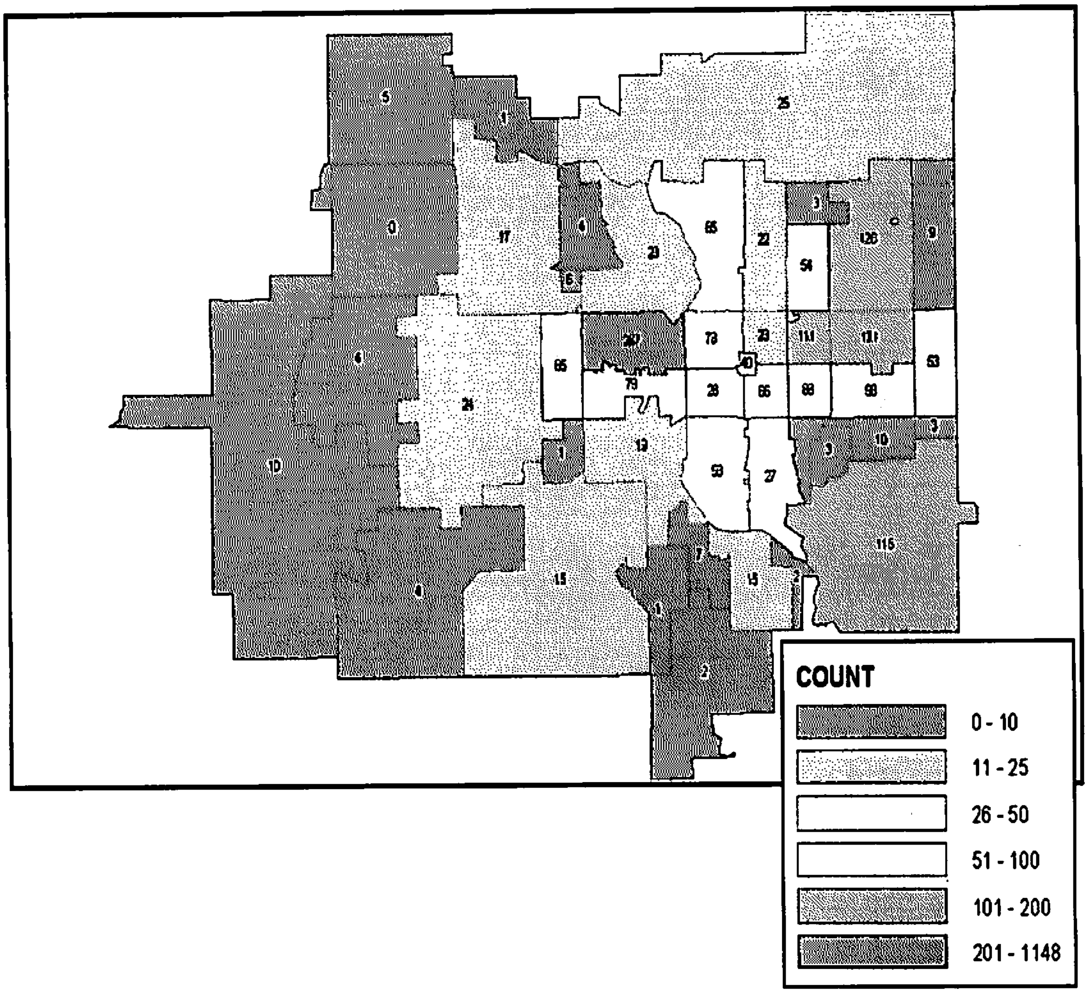


Figure 8. Sedgwick County and the Wichita Metropolitan area zip code districts listed by their total n-value of radon tests.

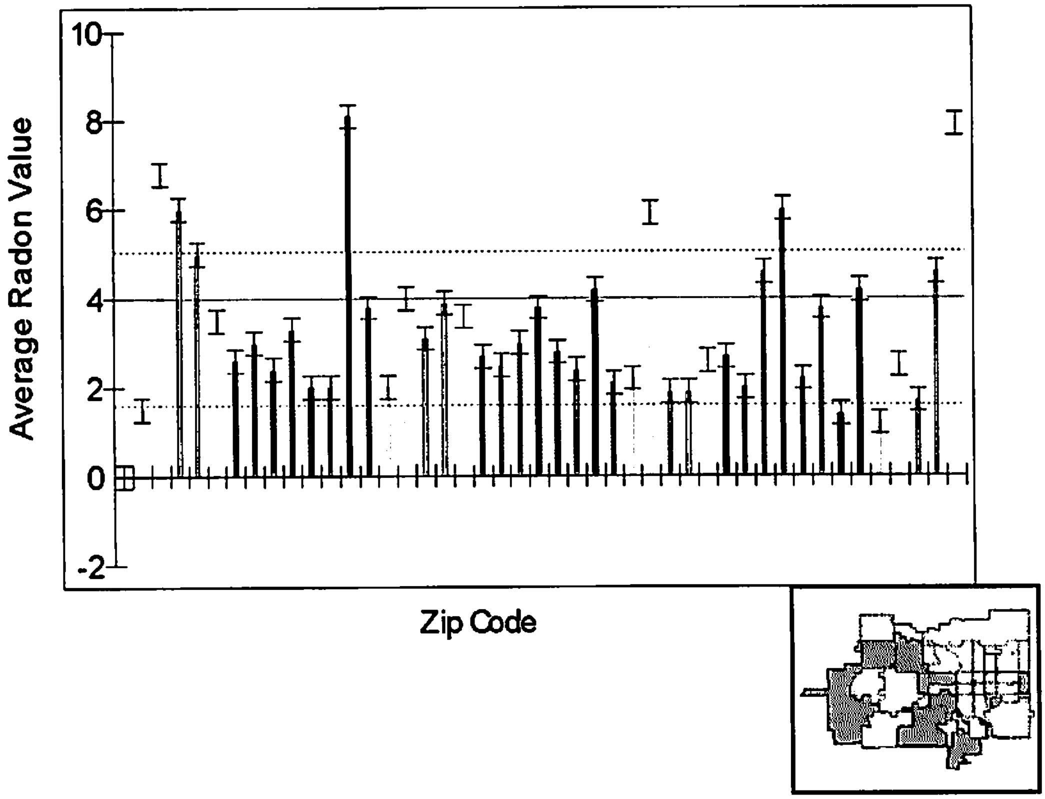


Figure 9. Sedgwick County and the Wichita Metropolitan area by average radon value. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

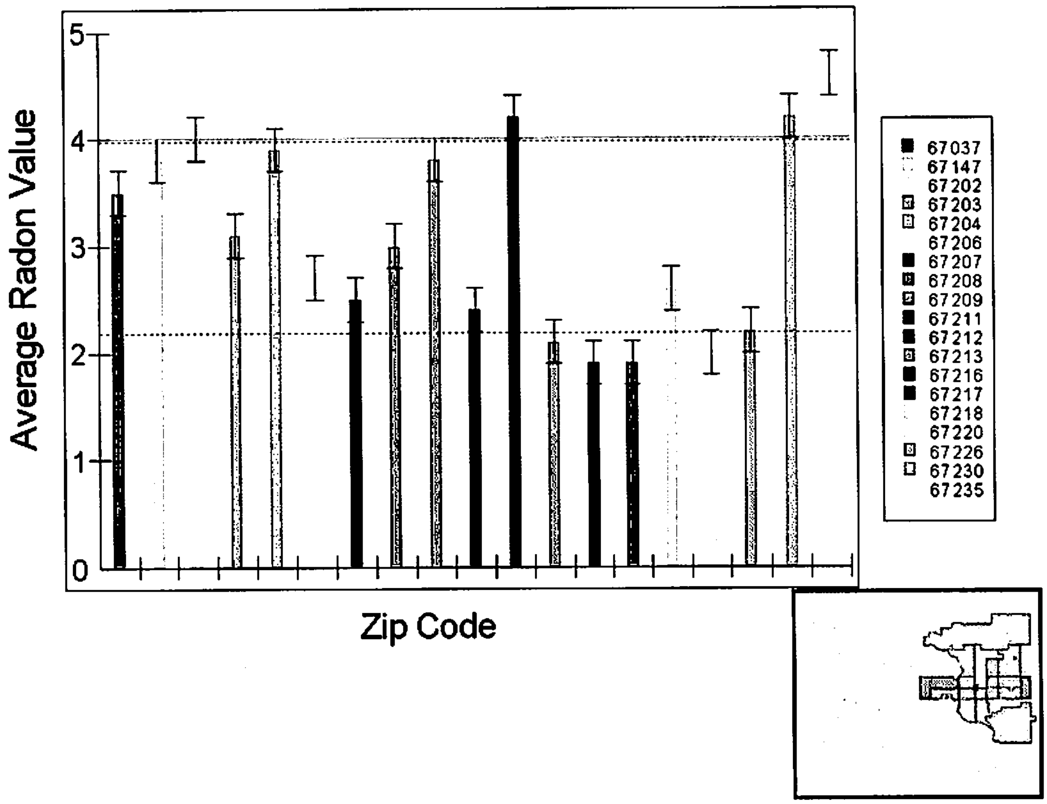


Figure 10. Sedgwick County and the Wichita Metropolitan area by average radon value. Zip code districts with 25 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

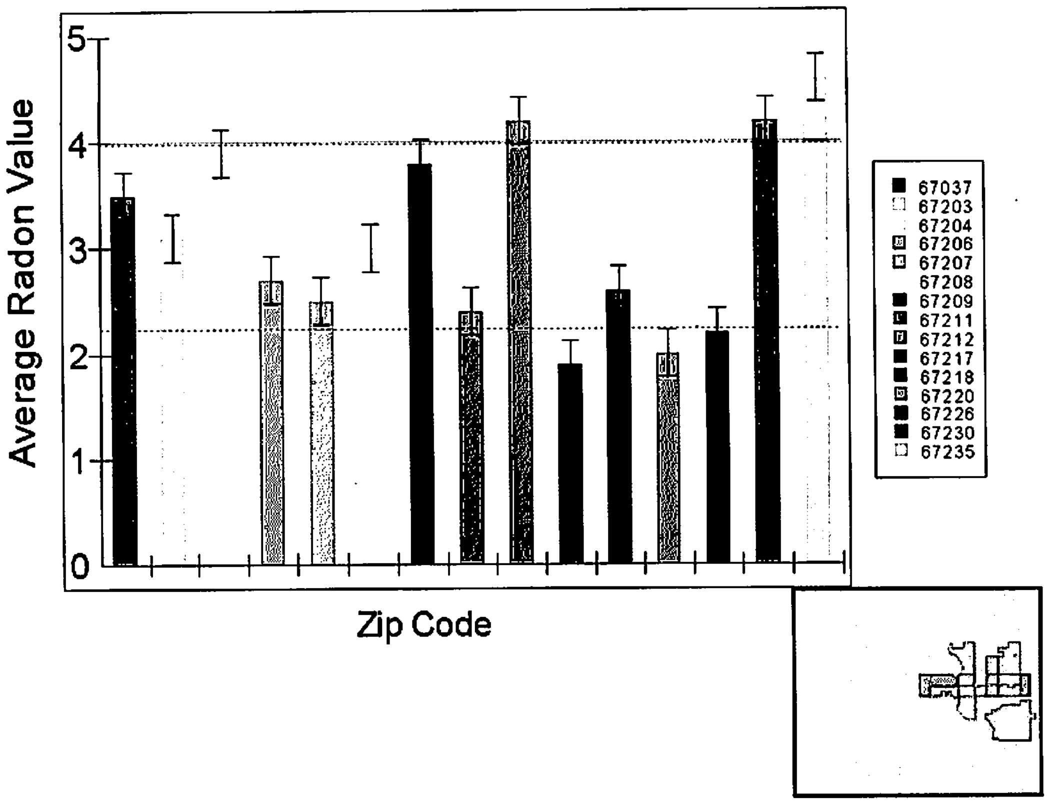


Figure 11. Sedgwick County and the Wichita Metropolitan area by average radon value. Zip code districts with 50 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

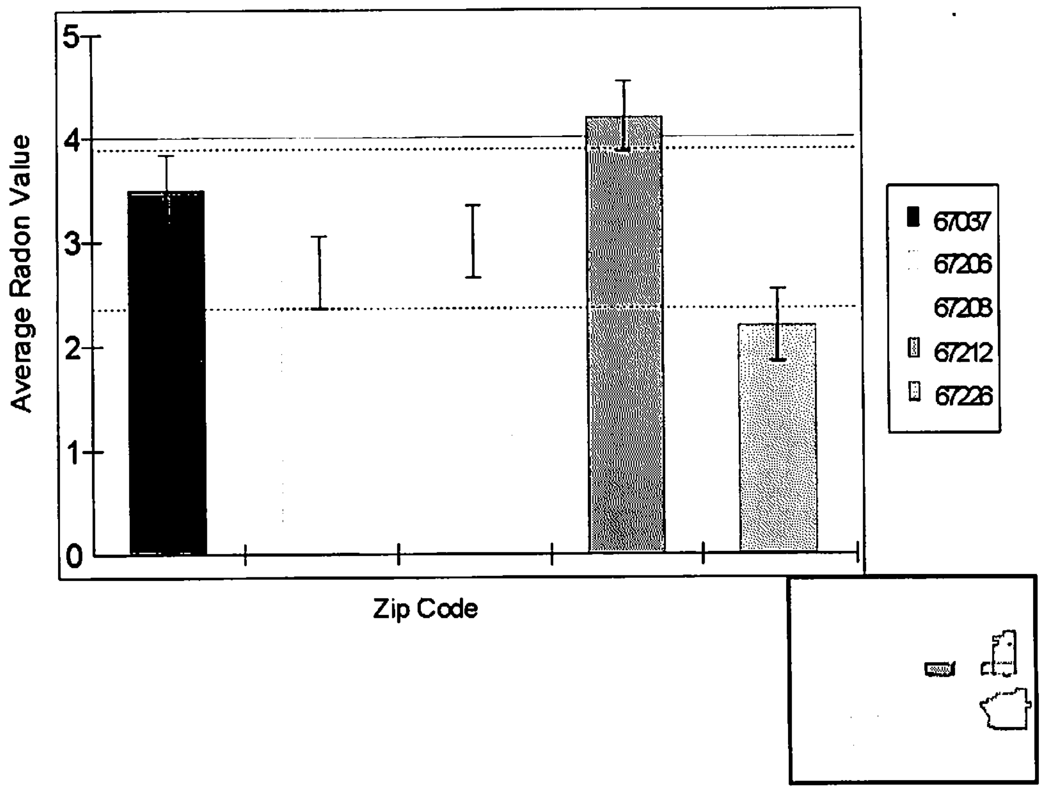


Figure 12. Sedgwick County and the Wichita Metropolitan area by average radon value. Zip code districts with 100 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

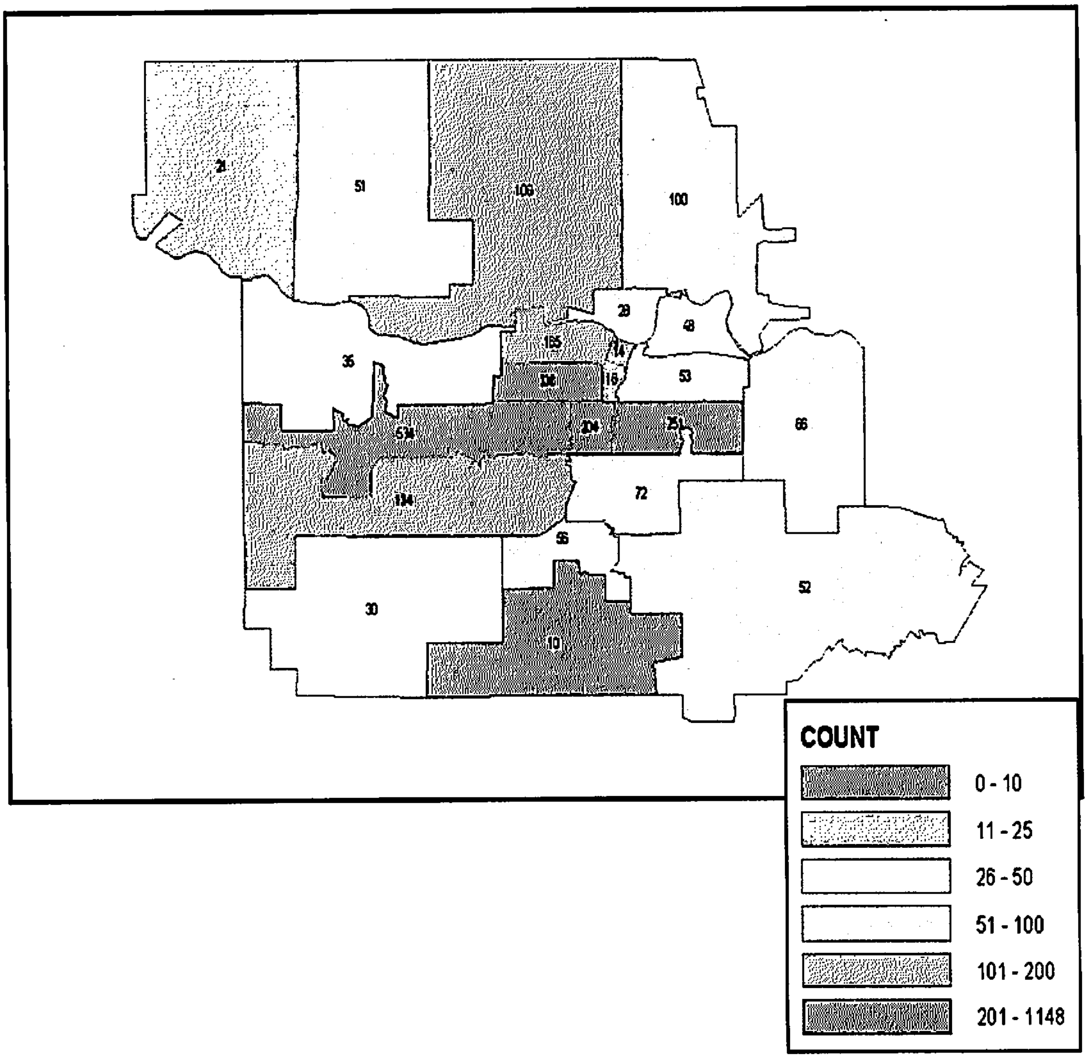


Figure 13. Shawnee County and the Topeka Metropolitan area zip code districts listed by their total n-value of radon tests.

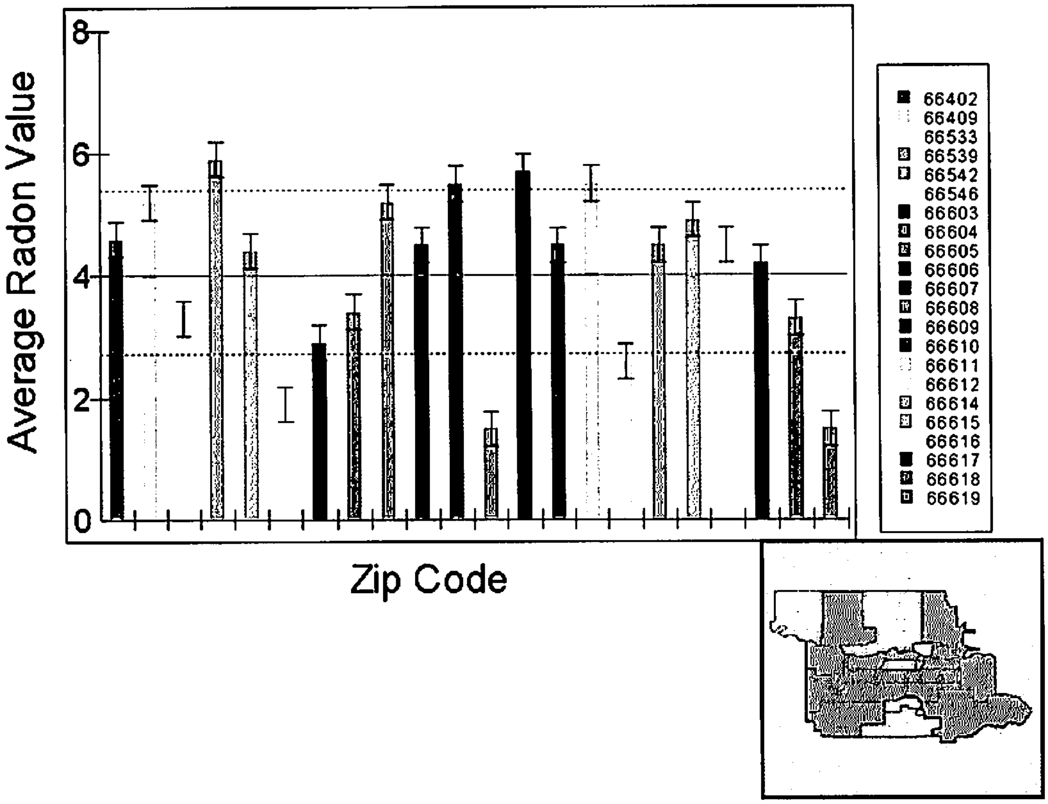


Figure 14. Shawnee County and the Topeka Metropolitan area by average radon value. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

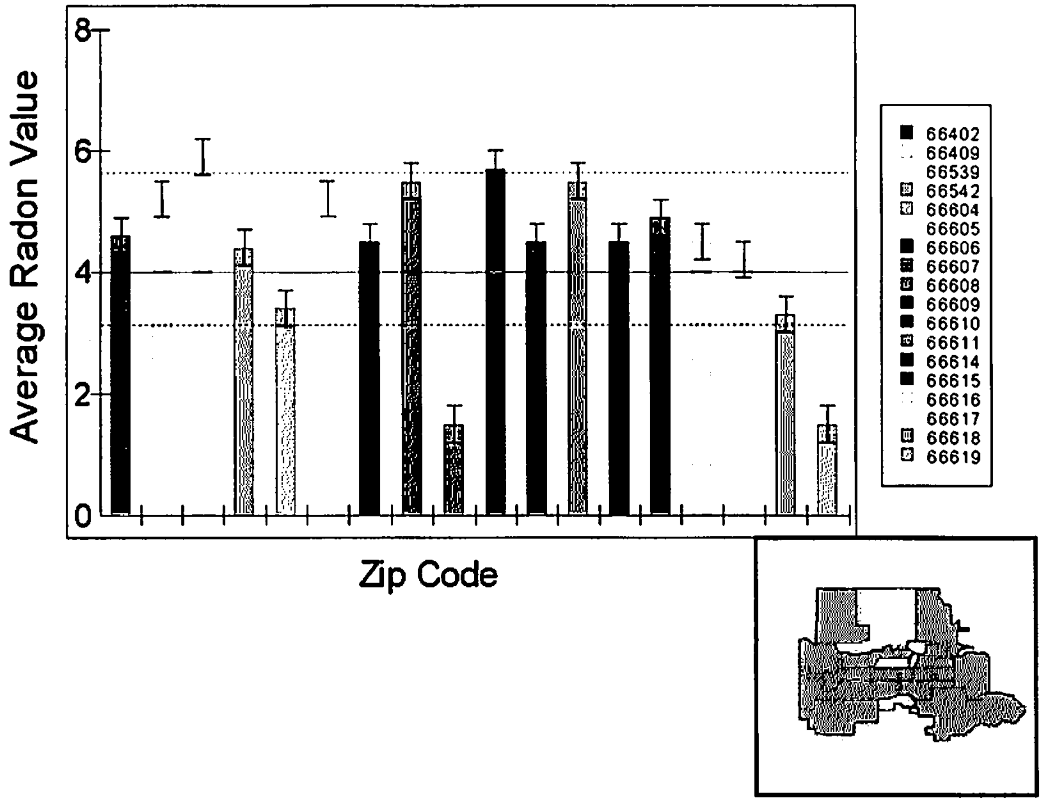


Figure 15. Shawnee County and the Topeka Metropolitan area by average radon value. Zip code districts with 25 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

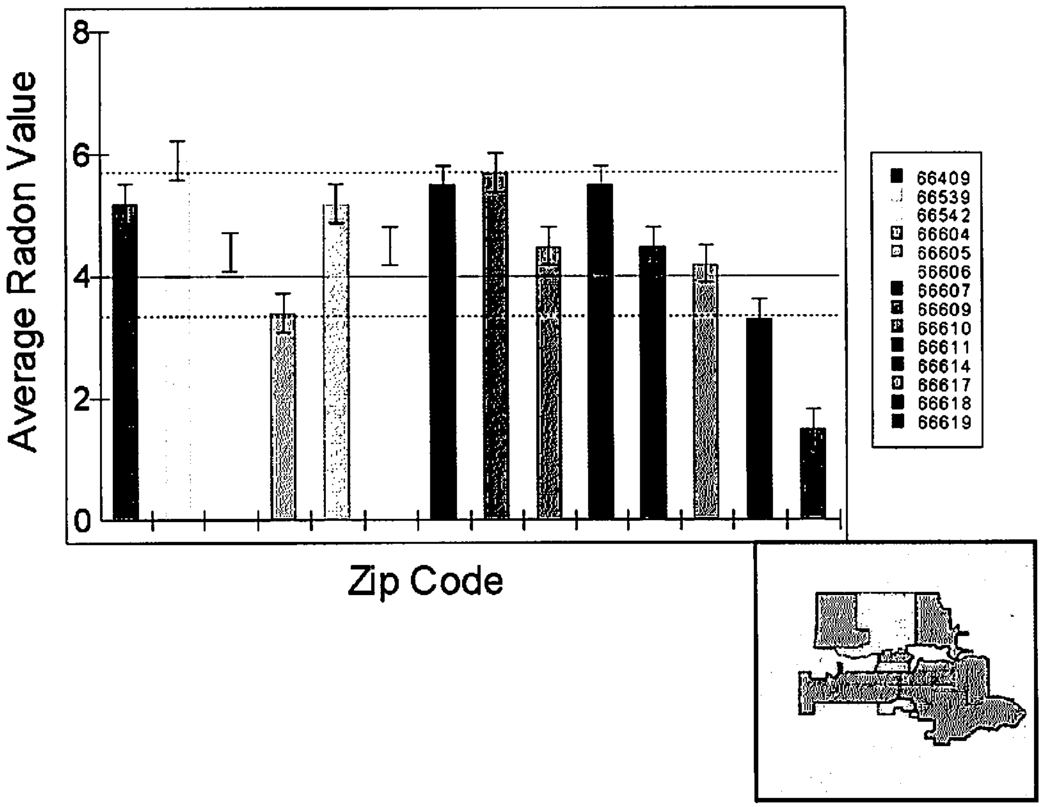
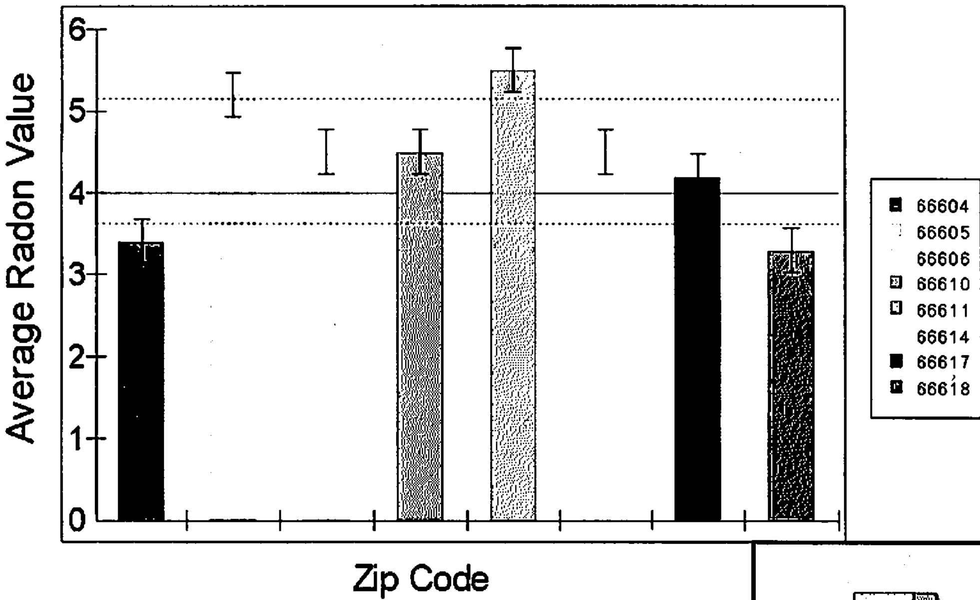


Figure16. Shawnee County and the Topeka Metropolitan area by average radon value. Zip code districts with 50 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.



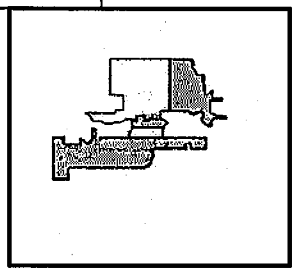


Figure 17. Shawnee County and the Topeka Metropolitan area by average radon value. Zip code districts with 100 or more tests are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

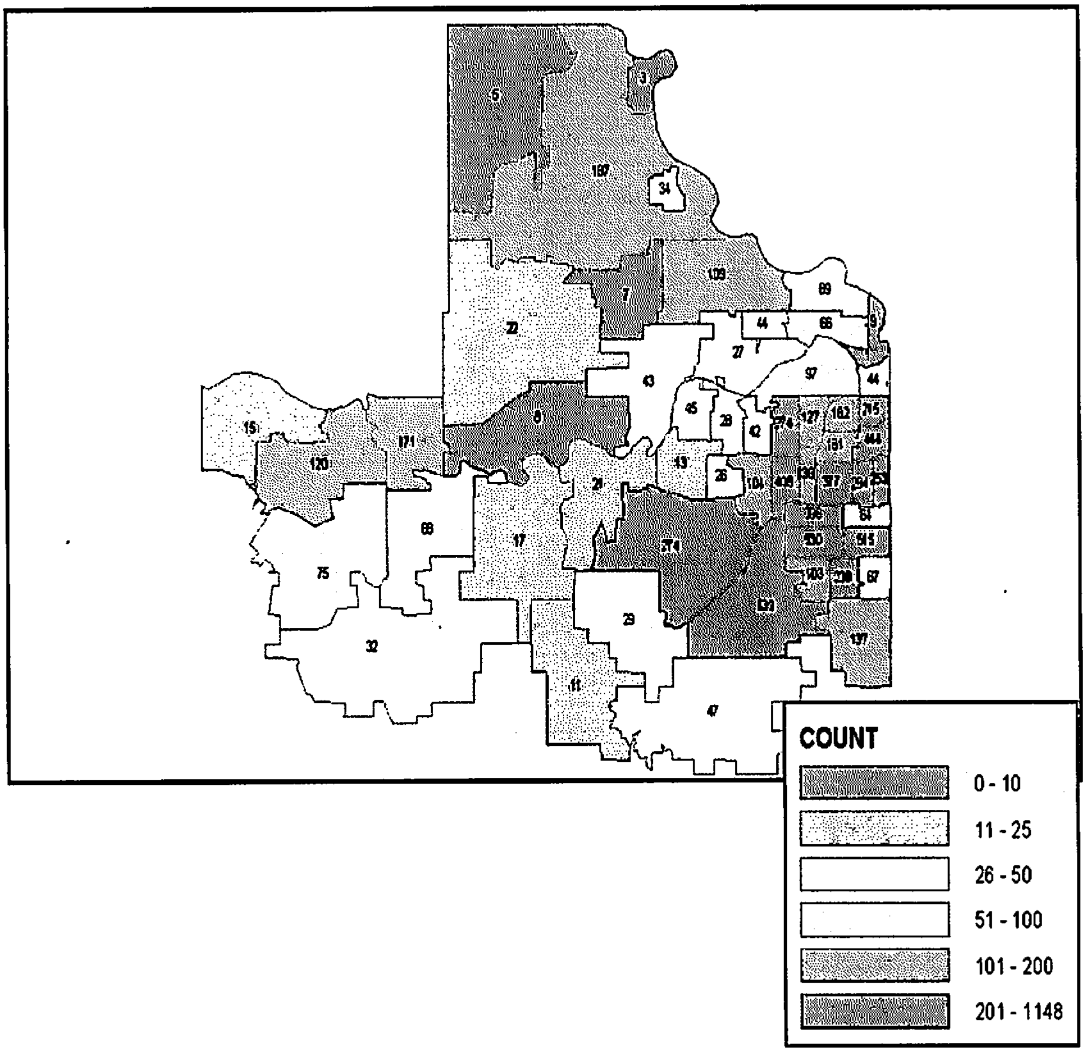


Figure 18. The Kansas City Metropolitan area (including Johnson, Douglas and Wyandotte counties) zip code districts listed by their total n-value of radon tests.

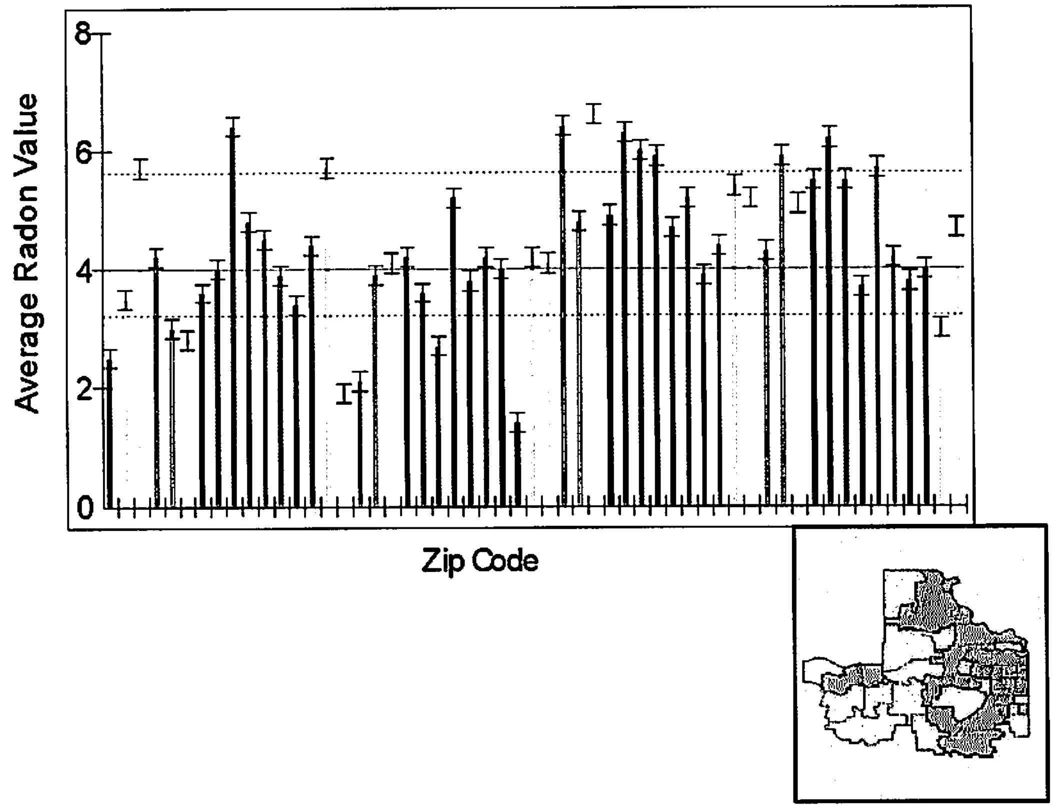


Figure 19. Kansas City Metropolitan area (including Johnson, Douglas, Leavenworth and Wyandotte counties) listed by average radon value. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

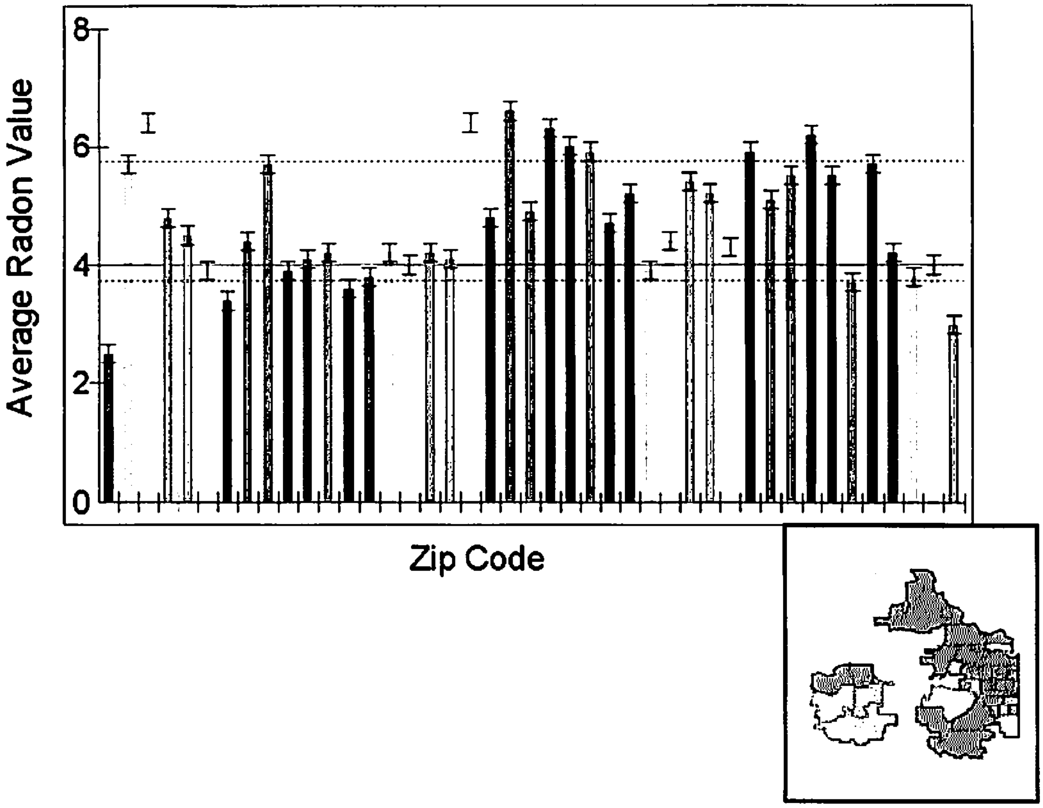
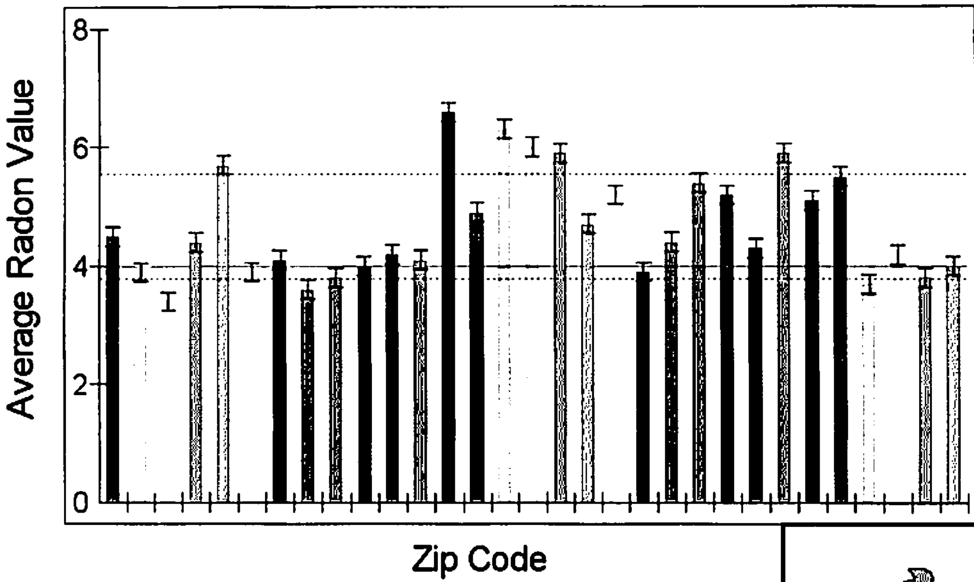


Figure 20. Kansas City Metropolitan area (including Johnson, Douglas, Leavenworth and Wyandotte counties) by average radon value. Zip code districts with 25 or greater test results are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.



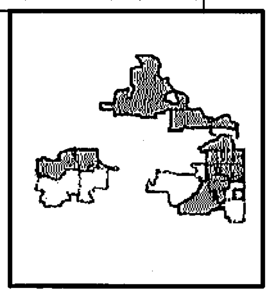


Figure 21. Kansas City Metropolitan area (including Johnson, Douglas, Leavenworth and Wyandotte counties) by average radon value. Zip code districts with 50 or greater test results are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.

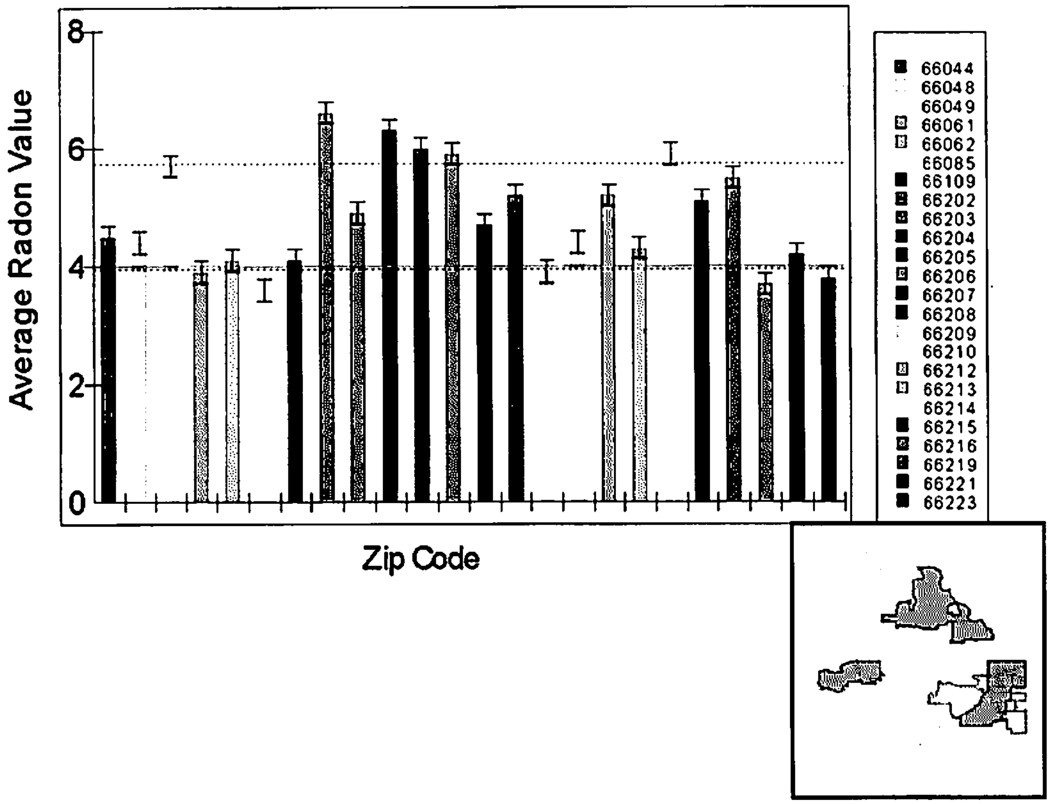


Figure 22. Kansas City Metropolitan area (including Johnson, Douglas, Leavenworth and Wyandotte counties) by average radon value. Zip code districts with 100 or greater test results are listed. Light green zip codes average less than 2.0 pCi/L indoor radon concentrations. Orange zip codes average between 2.0 and 4.0 pCi/L indoor radon concentrations. Red zip codes average 4.0 pCi/L indoor radon concentrations. Dark green zip codes have no data collected.