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KANSAS PRIVATE WATER WELLS SURVEY

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ABSTRACT

The potential for high radon in private well-water is a particular concern in Kansas where about 360,000 rural residents (about 16 % of Kansas population) use groundwater from private supplies wells as their primary water source. Because of the costly expense associated with monitoring, a national systematic survey of radon in private well-water has not been performed. In Kansas, a state wide radon survey of private wells was conducted between June and September 1995.

This survey was the first of its kind in Kansas that addressed:

-To what extent are rural Kansas residents, who utilize private well water, being exposed to indoor radon off-gassed from waterborne radon?

-What percentage of private well sites sampled have radon concentrations that exceed the maximum concentration (MCL) limits for public drinking water supplies?

-Are there any regional radon distribution trends in Kansas well-water?

-Do private well-water supplies in Kansas have higher concentrations of radon than Kansas public ground-water supplies?

-Do well-water radon concentrations vary compared to sub geology in Kansas?

While radon level will be determined in a sub-population of private wells, the primary thrust of this survey will be to examine the radon level in a sample of 500 private wells in Kansas.

INTRODUCTION

Many of the rocks and soils in Kansas have the potential to generate levels of radon exceeding that of the US Environmental Protection Agency (USEPA) action level [1].

Indoor Radon Data in Kansas

Indoor radon screening measurements from 2,031 homes sampled in the State/EPA Residential Radon Survey conducted in Kansas during the winter of 1987-1988 are shown in figure 1. The maximum value recorded in the survey was 48 pCi/L in Marshall county, 25.8 % of the measurements exceeded 4 pCi/l, state average was 3.51 pCi/l, standard deviation was 3.74 pCi/l, standard error of the mean was ±0.083, coefficient of variation was 106 %. Except for counties in the Kansas City, Topeka, and Wichita areas, most counties in the survey are represented by 20 or fewer indoor radon measurements; 19 counties have more than 20 measurements.

Based on State/EPA survey most counties in southeastern and south-central Kansas have low (0-2 pCi/l) to moderate (2-4 pCi/l) indoor radon averages. Counties in northeastern Kansas have moderate to high (> 4 pCi/l) indoor radon averages. Most of the counties in north-central and central Kansas have high indoor radon averages, and western Kansas has an approximately equal mixture of counties with moderate and high indoor radon averages

(Fig. 1). The highest maximum radon readings occurred in northeastern and central Kansas[1].

The Kansas statewide indoor radon database has been expanded to 15,495 data points (Fig.2). This database includes the initial 1987-1988 survey data and subsequently obtained screening measurements from RPP listed companies. The maximum value recorded in this database is 204 pCi/l in Clay county. The state average radon level is 4.35 pCi/l, the number of measurements above EPA action level were 5,646 (36.5% up from 25.8%), standard deviation is 6.06, standard error of the mean is ±0.048, coefficient of variation 139 %.

STATEWIDE PRIVATE WATER WELL SURVEY

The Statewide Private Water Well Survey (SPWWS) sampling frame was used from June to September, 1995 to assess radon concentrations in private well-water by collecting samples from 500 private wells. A sampling kit containing four 20 ml vials along with a detailed instruction sheet were sent to local sanitarians and members of the flood state response team working on phase II of the Center for Disease Control (CDC) study (targeted private wells that been affected by the flood of 1993). The team members collected their samples and took the time to collect the radon samples. Water samples were sent in to the Kansas Department of Health and Environment (KDHE) lab within 24 hours for analysis.

Sample Collections

The sample collection team were trained to obtain the samples using EPA Sampling Procedures. Generally, the training focused on collecting the sample in a manner that minimized radon lost to the atmosphere. Instructions which accompanied the collection kit included questions regarding collection site, collection time and any other information that was worth noting. The instructions directed the sample collectors to use a 20 ml vial to obtain a sample of water from an indoor faucet. The cold water faucet was allowed to run for about 10 minutes before the sample was collected. During the sampling the water was run allowed to run slowly to eliminate air bubbles from being introduced into the sample, and then the vial was capped as quickly as possible and returned promptly to the lab.

Analysis of Samples

- Apparatus

. Sample collection kits.

. Liquid scintillation counting system with automatic sample changer (Beckman-230, Wallaz 1409)

- Reagents

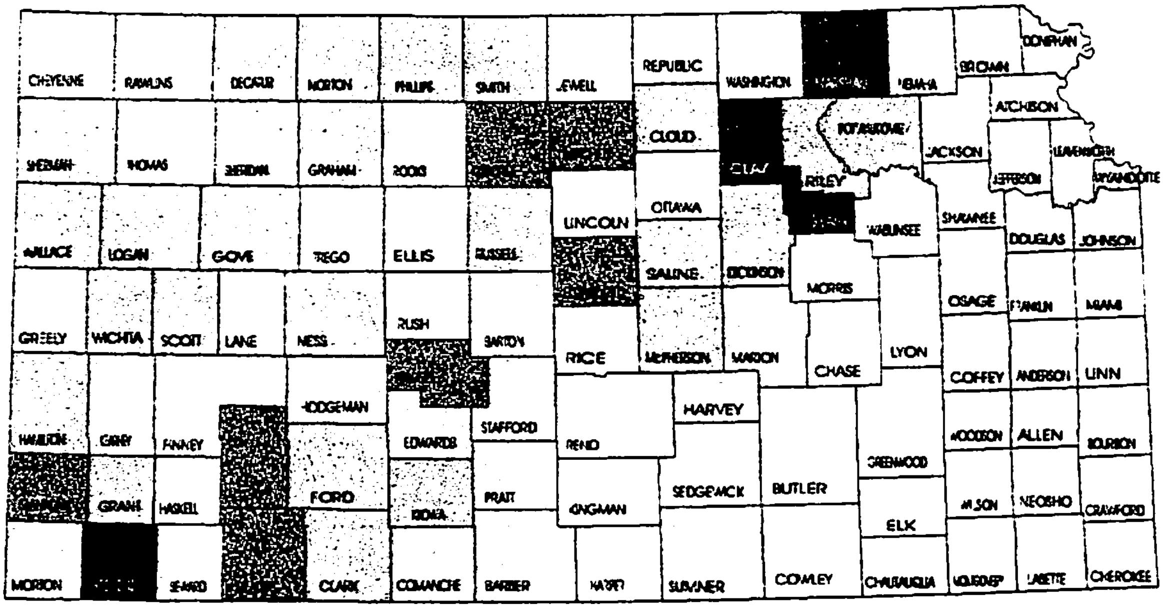
. Scintillation counting solution: mineral oil based scintillator (New England Nuclear Corp. Cat.# PSS-007H) or Opti-Fluor O (Puckered Instrument Co.)

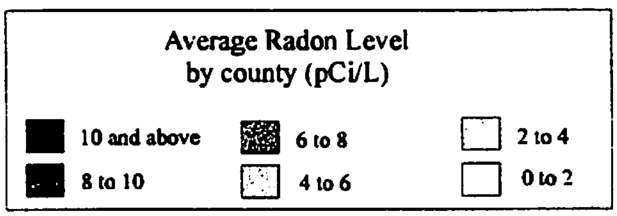
- Calibrations

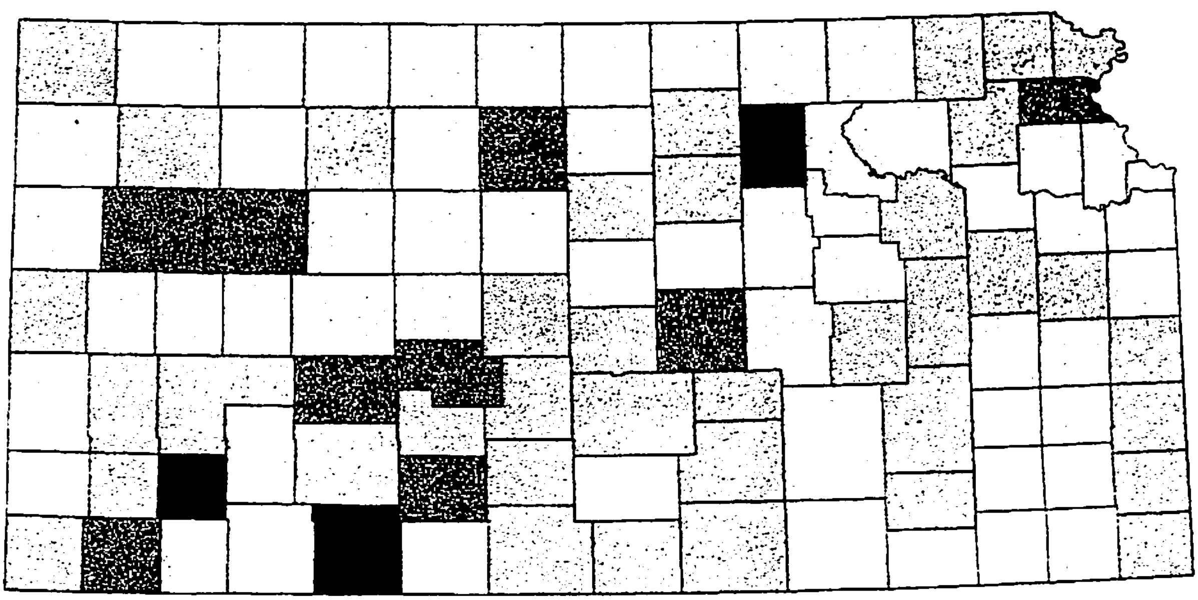
. Counter Efficiency

1. Add a known quantity of Ra-226 standard solution to a known volume of water.
2. Combine 10 ml aliquot of the Ra-226 standard solution with 10 ml of the scintillation counting solution in a 1.0 ml low potassium glass scintillation vial.
3. Allow approximately 21 days for buildup of radon daughters.
4. Count the standard and background samples for 50 minutes or longer.

(Fig. 1) 1987-1988 State/EPA Survey







(Fig. 2) Current State Database

5. Subtract the background cpm from the gross cpm for the standard and divide by the known radon activity (Rn-222 activity equals Ra-226 activity) to obtain the cpm/pCi conversion factor.

Procedures

1. A waiting period of at least 3 hours should be observed between the collection and counting of the sample in order to allow the ingrowth of Rn-222 daughters.
2. Before counting, the outer walls of the scintillation vial should be cleaned with ethyl alcohol.
3. At least one standard and one background sample should be counted in a set of samples to be analyzed.
4. Record the cpm of standard, background and samples and calculate Rn-222 concentrations in the samples[2].

Calculations

The pCi/l of Rn-222 in the sample were calculated by using the following equation :

$$\text{Rn-222 (pCi/l)} = ((Cs - Cb) \times 100) / CF \times D$$

Where

- Cs: Sample cpm
- Cb: Background cpm
- CF: Conversion factor (cpm/pCi)
- D: Decay correction = $\exp(-0.693 \times (T/t_{1/2}))$
  T:Time elapsed (day) between sample collection to midpoint of counting time.
  $t_{1/2}$:Half-life of Rn-222 (3.82 days)

Note: The analyst could use the Radiochemistry Laboratory computer program called "RNCAL" to calculate the Rn-222 concentration. The RNCAL will accept a set of duplicate analytical results then perform a statistical test (the 4-D test) to determine any outlives. The outlives will be rejected and the mean value of the duplicate results will be determined.

Quality Control

Triplicate analysis was performed for each sampling location. Each batch of samples were analyzed along with a QA sample and a standard. The QA sample had a known quantity of Rn-222 (Ra-226). The batch of samples was recounted whenever the result of the QA sample was out of the control limit.

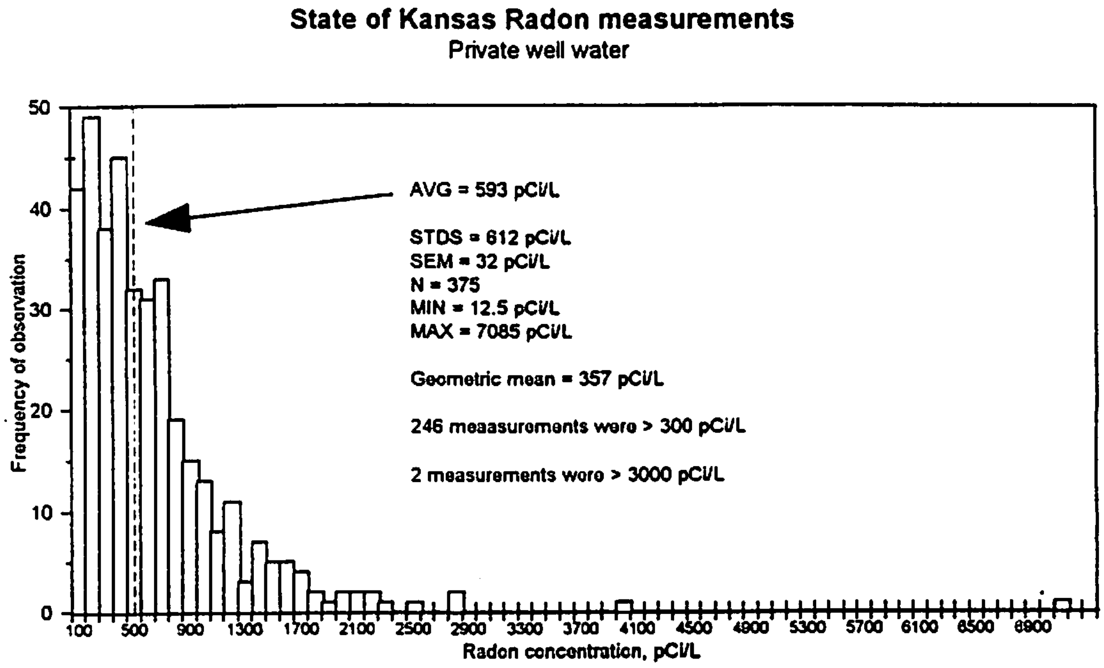
The holding time of Rn-222 sample was four days. Samples which exceeded the holding time were analyzed as well. However, a remark indicating the sample exceeded the required holding time was reported.

Detection Limit

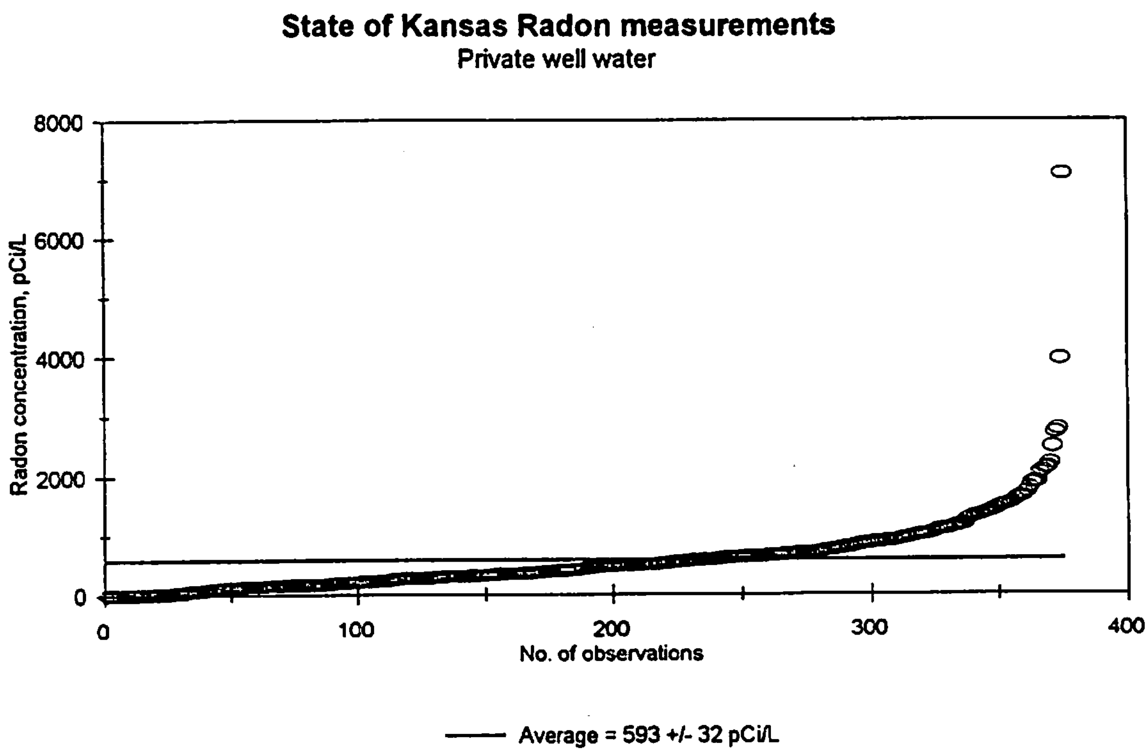
A detection limit of 25 pCi/l was achieved with the described method when 10 ml of water sample was counted for 60 minutes with the liquid scintillation analyzer.

SUMMARY OF THE STATEWIDE PRIVATE WATER WELL STUDY

Data that met any of the following exclusion criteria were eliminated from summary data set: water sample received after four days, water samples with leaky or broken vial, water samples with no information on location, and water samples with less than ten ml of water. Satisfactory samples for inclusion in the summary (SPWWS) data set were obtained from 383 sites. The radon concentration in the samples ranged from 25 pCi/l to 7,085 pCi/l in Logan County, with an average of 593 pCi/l, standard deviation 612.36 pCi/l, standard error ±31.29 pCi/l. About 63.4% percent exceeded 300 pCi/l and only two measurements exceeded 3,000 pCi/l (Fig 3,4).


State of Kansas Radon measurements
Private well water
AVG = 593 pCi/L
STDS = 612 pCi/L
SEM = 32 pCi/L
N = 375
MIN = 12.5 pCi/L
MAX = 7085 pCi/L
Geometric mean = 357 pCi/L
246 meaasurements were > 300 pCi/L
2 measurements were > 3000 pCi/L
Frequency of observation
Radon concentration, pCi/L

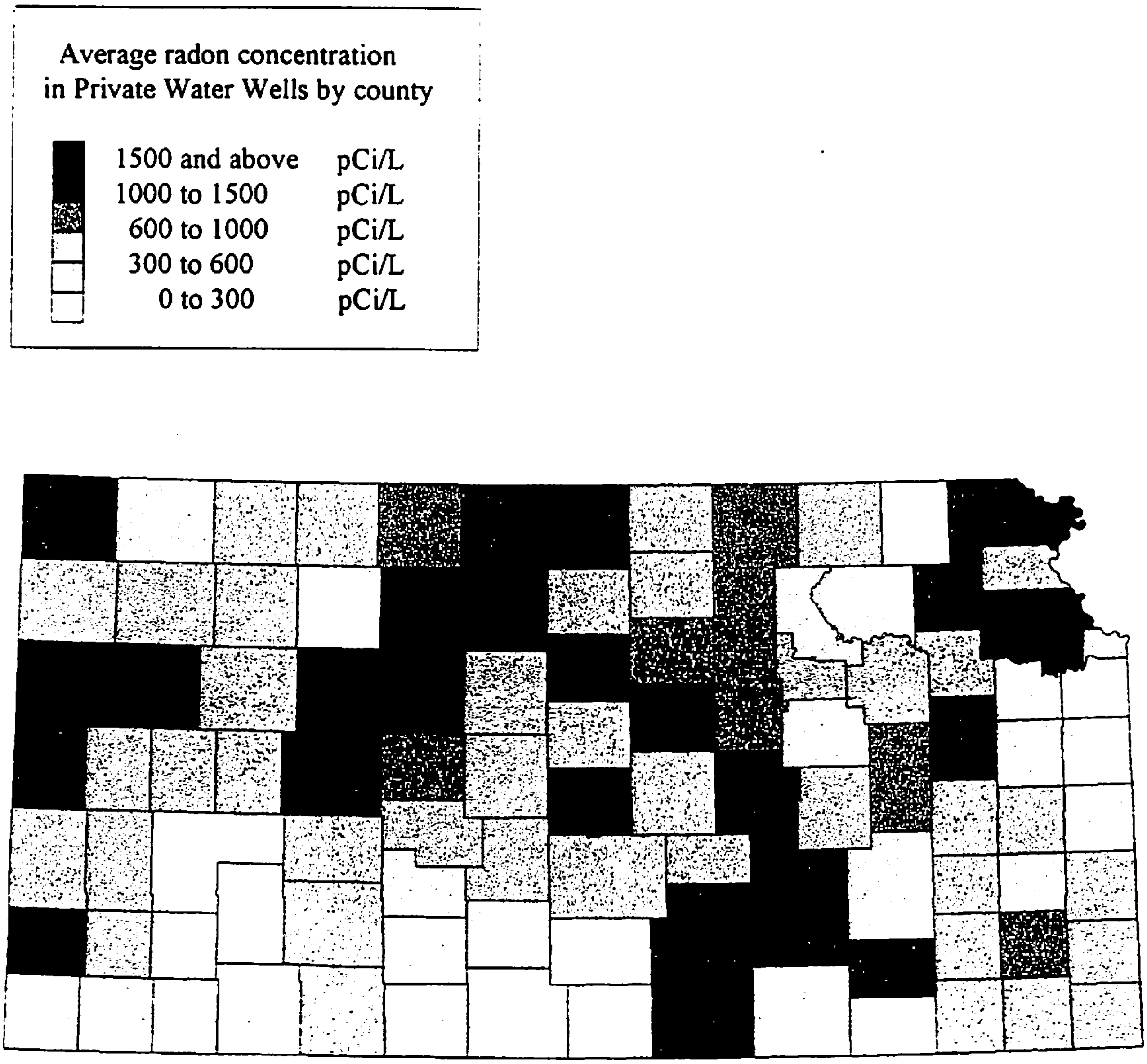
(Fig. 3)


State of Kansas Radon measurements
Private well water
Radon concentration, pCi/L
No. of observations
Average = 593 +/- 32 pCi/L

(Fig. 4)

Presenting The Data

Using Mapinfo, a desktop mapping system, the data were assigned coordinates for each record so that the system knows where to spot the record on the map. This process is known as geocoding. Once the geocoding was completed, the data were ready to be displayed on the map. The data were presented on a county level reflecting that county's average, also the data can be presented on zipcode or street address level; but for confidentiality reasons the average on a county level have been selected (Fig.5).



(Fig. 5)

EPA'S MAP OF RADON ZONES

The USGS Geologic Radon Province Map is the technical foundation for EPA's Map of Radon Zones. The Map of Radon Zones is based on the same range of predicted screening levels of indoor radon as USGS Geologic Radon Province Map. EPA defines the three zones as follows: Zone One areas have an average predicted indoor radon screening potential greater than 4 pCi/L. Zone Two areas are predicted to have an average indoor radon screening potential between 2 pCi/L and 4 pCi/L. Zone Three areas are predicted to have an average indoor radon screening potential less than 2 pCi/l [3](Fig 6).

Kansas Map of Radon Zones

The Kansas Map of Radon Zones and its supporting documentation have received extensive review by Kansas geologists and radon program experts. The Map of Radon Zones for Kansas generally reflects current state information on radon levels in all counties [3].

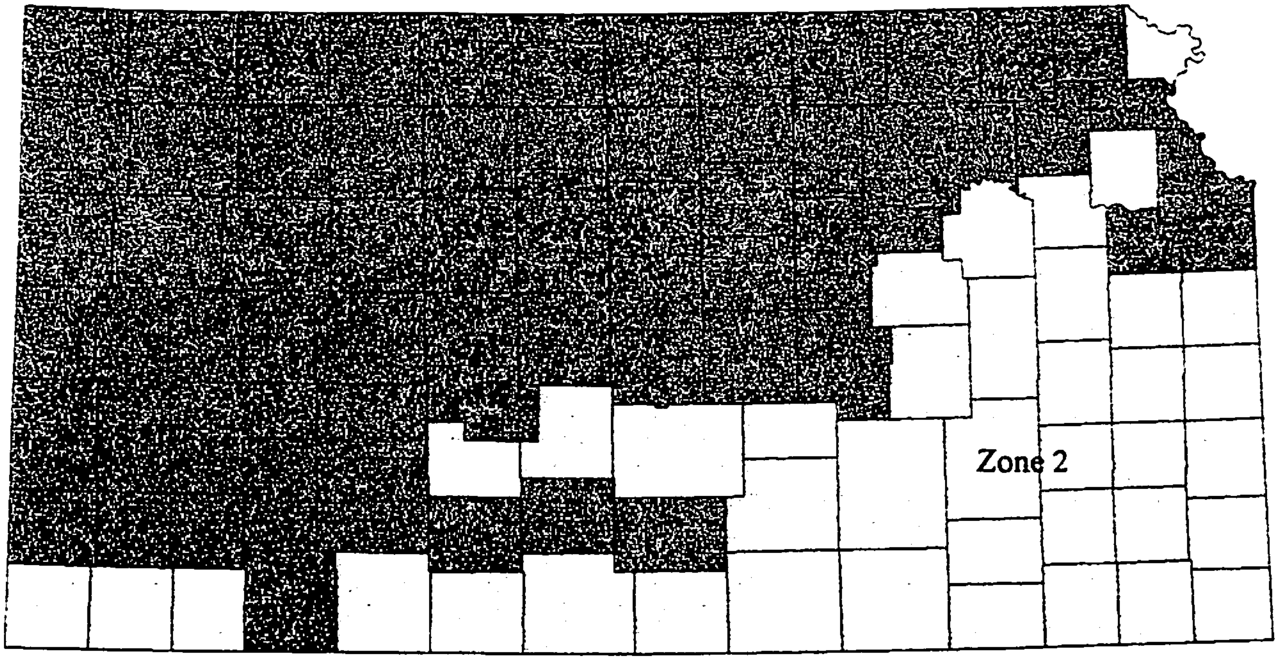
Geologic Radon Potential

For the purposes of this assessment, Kansas is divided into six geologic radon potential areas (Fig. 7). Each area is assigned Radon Index (RI) and Confidence Index (CI) scores (Table 1). The Radon Index is a semiquantitative measure of radon potential based on geologic, soil, and indoor radon factors. The Confidence Index is a measure of the relative confidence of the RI assessment based on the quality and quantity of data used to make the predictions. At the scale of this report the outlines of the areas shown on figure 9 are generalized, and the descriptions given in this text should be compared with more detailed geologic and other maps [3].

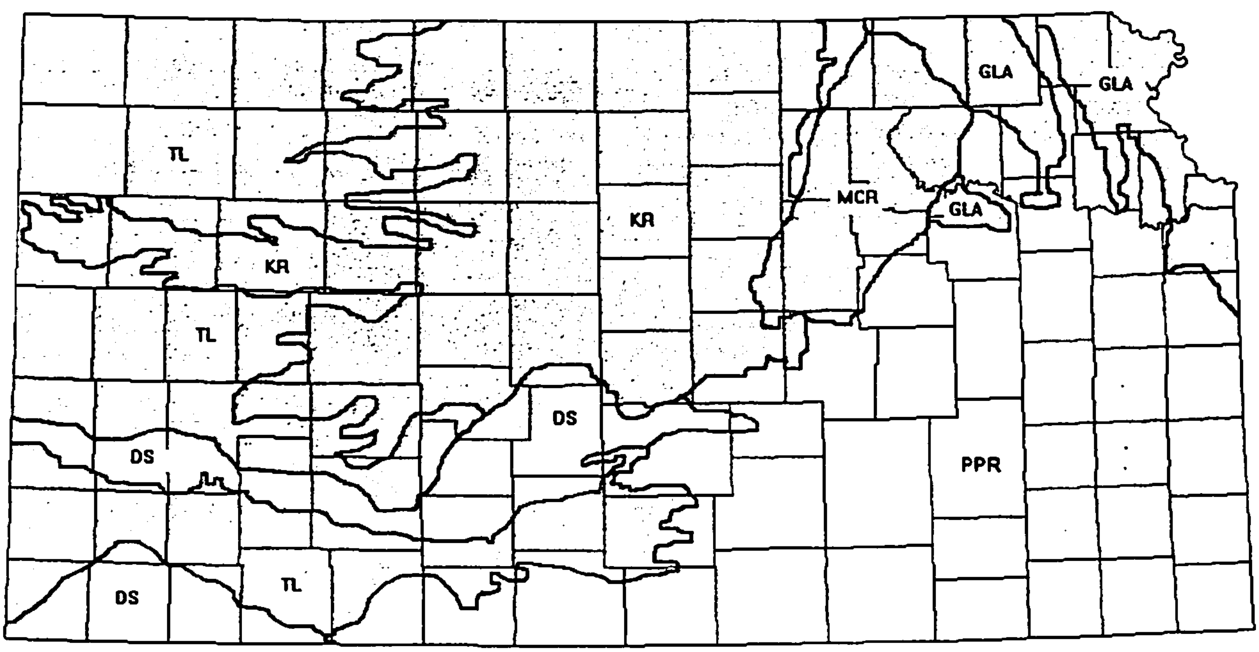
Area PPR is underlain by Pennsylvanian and Permian rocks. Homes in this area may have indoor radon levels ranging from low (<2 pCi/l) to high (>4 pCi/l), depending on the local underlying geology and presence and thickness of loess cover. Additional indoor radon data compiled by the Kansas Department of Health and Environment (written communication, 1992) suggest that more homes in this area have moderate to high indoor radon levels than are indicated by the State/EPA Residential Radon Survey data. As a consequence the indoor radon factor was assigned 2 points, but because the data was partially from a non-randomly-sampled volunteer source, the factor was given 2, rather than 3, confidence index points. Homes built on uranium-bearing Pennsylvanian black shales within this area may have locally high indoor radon levels. Some areas underlain by carbonate rocks (limestones and dolomites) may have locally elevated indoor radon levels, especially if solution features or clay-rich residual soils have developed (the residual soils are commonly red or orange-red in color due to concentration of iron oxides in the residuum). Some domestic wells drawing water from lower Paleozoic aquifers in this area may contribute to elevated radon levels by release of dissolved radon from the water into the indoor air. Area PPR is assigned a moderate or variable overall radon potential (RI=9) with moderate confidence (CI=9) [3].

Area GLA is underlain by glacial drift and loess of varying thickness. Although the bedrock source for the glacial drift can be traced as far as the Canadian Shield, a large proportion of the drift is relatively locally derived from underlying and nearby Paleozoic sedimentary rocks that are relatively poor radon sources. Higher permeability of the drift relative to bedrock, the presence of crystalline glacial erratics, and the variability of loess cover and source (primarily glacially derived) cause this area to have moderate to high radon potential, and it is assigned an overall high geologic radon potential (RI=12), with a high confidence index (0=10) [3].

Area MCR is an area of faults and fractures related to the Mid-Continent Rift zone. Homes sited on unfaulted Permian bedrock in this area are likely to have low radon levels, but those sited on surface or near-surface faults or fractures may have locally high indoor radon levels. The boundaries of the area are drawn along major subsurface faults that delineate the rift system (Berendsen and others, 1989). Overall, area MCR is assigned a high radon potential (R. =12) with high confidence (0=10) [3].



(Fig. 6) EPA'S MAP OF RADON ZONES FOR KANSAS



(Fig. 7) Geologic Radon Potential Areas of Kansas

Area KR delineates the bedrock outcrop pattern of Cretaceous sedimentary rocks in Kansas. Parts of this area, particularly the western part are covered by discontinuous loess deposits. Gray and black shale Units of the Pierre Shale typically generate moderate to high indoor radon levels. The Dakota and Nebraska Formations and the Pierre Shale are known to contain locally anomalous amounts of uranium and are known producers of elevated radon in some areas. Overall, area KR has a high radon potential (RI= 1 2) with high confidence (CI= 1 1) [3].

Area TL is mostly underlain by Tertiary rocks, specifically the Ogallala Formation, that are mostly covered by younger loess deposits. The highest radon levels in this area are expected to occur in homes sited on siliceous (silica-cemented) Ogallala Formation, particularly in the southwestern part of the State. Radon levels in structures built on loess deposits are expected to range from moderate to high depending on the thickness and mineralogy of the loess. Because the indoor radon data indicate that many areas underlain by loess or Tertiary sedimentary rocks have county average indoor radon levels exceeding 4.0 pCi/L, and because many of the counties in western Kansas have relatively few sampled homes in the State/EPA survey, a conservative approach to ranking the area was adopted. Indoor radon levels in this area are expected to range from low (< 2 pCi/L) to high (> 4 pCi/L) but are most likely to be in the moderate to high range, so area TL is assigned an overall high radon potential (RI= 12) with high confidence (CI= 11) [3].

DS denotes areas underlain by dune sands in the Arkansas and Cimarron River valleys. The dune sands are highly permeable, but because they are composed almost entirely of quartz grains containing little or no uranium or radium, they generally generate low radiation levels. If the deposits are thin (less than approximately 15 ft thick), the sands are likely to transmit radon from the underlying bedrock toward the ' surface and into homes built on these deposits. Relatively higher indoor radon levels are also more likely to occur where the sands are mixed with loess deposits. Area DS is assigned a moderate or variable geologic radon potential (RI=10), with a high confidence index (CI=1 1) (Table 1) [3].

TABLE 1. Radon Index (RI) and Confidence Index (CI) scores for geologic radon potential areas of Kansas. See figure 7 for locations of areas [4].

	AREA											
	PPR		GLA		MCR		KR		TL		DS	
FACTOR	RI	CI	RI	CI	RI	CI	RI	CI	RI	CI	RI	CI
INDOOR RADON	2	2	2	3	3	3	2	3	2	3	2	3
RADIOACTIVITY	2	3	2	2	2	3	2	3	2	3	1	3
GEOLOGY	2	2	3	3	3	2	3	3	3	3	2	3
SOIL PERM.	1	2	2	2	1	2	2	2	2	2	2	2
ARCHITECTURE	2	-	3	-	3	-	3	-	3	-	3	-
GFE POINTS	0	-	0	-	0	-	0	-	0	-	0	-
TOTAL	9	9	12	10	12	10	12	11	12	11	10	11
RANKING	M	M	H	H	H	H	H	H	H	H	M	H

RADON INDEX SCORING:		Probable screening indoor
Radon potential category	Point range	radon average for area
LOW	3 - 8 points	< 2 pCi/L
MODERATE/VARIABLE	9 - 11 points	2 - 4 pCi/L
HIGH	> 11 points	> 4 pCi/L

Possible range of points = 3 to 17

CONFIDENCE INDEX SCORING:	
LOW CONFIDENCE	4 - 6 points
MODERATE CONFIDENCE	7 - 9 points
HIGH CONFIDENCE	10 - 12 points

Possible range of points = 4 to 12

CONCLUSION

- Based on the finding of the this survey, and considering the ratio 10,000/1 pCi/l (10,000 pCi/l radon in water will contribute to 1 pCi/l to indoor air) there is a very small sector of Kansans who utilize water from private wells that are being exposed to a small fraction of one pCi/l of indoor radon off-gassed from waterborne radon.

- Of the total private wells tested 63.4 % exceeded the early EPA proposed MCL of 300 pCi/l, and less than 1% exceeded the newly US Senate approved MCL of 3,000 pCi/l.

- Private well-water in Kansas have higher concentrations of radon (the highest measurement recorded is 7,085 pCi/l) than water from Kansas public ground water supplies (the highest measurement recorded is 5,024 pCi/l).

- There are eight sectors or regions clearly identified as follows: east and southeast regions ranging between minimum deduction to about 600 pCi/l, north east region ranging between 600 pCi/l to 1000 pCi/l, upper north of the state has two region one ranged from 1,000 pCi/l to 1,500 pCi/l, the second ranged from 600 pCi/l to 1,000 pCi/l, central region of the state ranging from 300 pCi/l to 600 pCi/l, south center region of the state ranging between minumum deduction to 300 pCi/l, the western region having the highest measurements ranged from 1,500 to 1,812 pCi/l.

- Comparing the results of the study with regards to the geologic radon potential areas of Kansas most regions meet the criteria closely except for the central region.

- The second phase of this survey is currently underway. This phase will investigate residences that utilize private water wells and which the radon measurements in the water were above 3,000 pCi/l.

REFERENCE

(1) R. Randall Schumann, Preliminary Geologic Radon Potential Assessment of Kansas, EPA'S Map of Radon Zones Kansas, EPA, September 1993.

(2) Radiation Chemistry Lab, Kansas Department of Health and Environment.

(3) EPA'S Map of Radon Zones Kansas, EPA, September 1993.

(4) Table 2, R. Randall Schumann, Preliminary Geologic Radon Potential Assessment of Kansas, reprinted from USGS open file report 93-292-G. Table presented in this paper is modified.