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Distribution of radionuclides in Wisconsin groundwater

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Title: Distribution of Radionuclides in Wisconsin Groundwater

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Period of Contract: July 1, 1991 to September 30, 1992

Objectives: Evaluate concentration and distribution of naturally occurring radionuclides in Wisconsin outside of the Department of Natural Resources North-Central District area in order to determine whether radionuclides are widely spread.

Background/ Need: Knowledge of the natural distribution of radionuclides such as radon in Central Wisconsin groundwater is well developed only in the north-central part of Wisconsin where naturally occurring radioactive constituents are present in groundwater at levels which exceed maximum contaminant levels specified or proposed by the Federal Safe Drinking Water Act. This study was undertaken to determine the magnitude and extent of naturally occurring radionuclides, principally radon, elsewhere in Wisconsin.

Methods: In conjunction with colleagues in the Department of Natural Resources and the Central Wisconsin Groundwater Center, 40 ml samples of groundwater from documented wells (having a Wisconsin Unique Well ID and a construction report) were submitted to the State Laboratory of Hygiene for radon in water analysis by liquid scintillation. Results are reported in picocuries per liter of water.

Results: Radon in groundwater occurs more widely spread than heretofore reported, and includes groundwater from dolomite aquifers in southern and eastern Wisconsin. Although elevated in comparison to the proposed EPA standard of 300 pCi/L, the elevated concentrations are much less than those found in central Wisconsin over granite. The only hydrogeologic unit found to be low in radon was sandstone with few impurities.

Analytical techniques and laboratories were evaluated, and it was found that the Wisconsin State Laboratory of Hygiene reports radon in water concentration on an average 20 percent higher than other EPA certified laboratories. This results in an overestimate of risk, and errs on the side of caution. The less expensive kits may be falsely reporting lower radon concentrations than actually occur.

Gross alpha and gross beta analyses do not provide insight into which radionuclides are present, and their continued use is discouraged in evaluating radon. They may serve well as an inexpensive indicator of radium or uranium, though.

Conclusions: Elevated levels of radon in groundwater are more wide spread than only the northcentral part of Wisconsin. Moderately elevated concentrations can be found in all areas of the state. Exceeding high (over 100,000 pCi/L) concentrations appear to be restricted to northcentral Wisconsin.

Recommendations/ Implications: Analysis of groundwater for radon should continue, and areas in eastern Wisconsin having granite bedrock geology, or surficial material derived from granite should be evaluated.

A more comprehensive evaluation of existing data should be undertaken to more fully evaluate the source of radon in groundwater in order to design well construction to minimize radionuclide contamination.

Availability of Report: A copy of the final report is Wisconsin Geological and Natural History Survey Open-file Report 93-4, Distribution of radionuclides in Wisconsin groundwater by M.G. Mudrey, Jr. and K.R. Bradbury and is available from the Map and Publications Sales Office, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, WI 53705.

Related Publications: Not any.

Key Words: radon, groundwater, radioactive constituents

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DISTRIBUTION OF RADIONUCLIDES IN WISCONSIN GROUNDWATER

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INTRODUCTION

Knowledge of the distribution of radionuclides such as radon and radium in Wisconsin groundwater is well developed only in the north-central part of Wisconsin (Fitzgerald, 1990) where naturally occurring radioactive constituents are present in groundwater at levels which exceed maximum contaminant levels specified or proposed by the Federal Safe Drinking Water Act. Eighty to ninety percent of wells sampled by Fitzgerald (1990) exceed the proposed standard of 300 pCi/L of radon in drinking water in northcentral Wisconsin. High levels of radium are documented in public water supplies in eastern Wisconsin (Hahn, 1990).

PROJECT GOALS

We undertook a preliminary sampling program to determine the magnitude and extent of naturally occurring radionuclides elsewhere in Wisconsin. We were assisted by the Central Wisconsin Groundwater Center, and the Wisconsin Department of Natural Resources North-central District Office.

The original proposal suggested that screening for gross alpha, gross beta, uranium, radon and radium from private and small public water supplies such as schools and small municipalities might provide needed information on the distribution and magnitude of the naturally occurring radionuclides. In discussion with the Wisconsin State Laboratory of Hygiene, we determined that some of the radionuclide tests did not provide definitive information to evaluate which isotope might be elevated in groundwater, and that the cost of screening followed by detailed analysis was financially unrewarding.

METHODOLOGY - Radionuclide Comparison

Techniques for measuring gross radiation were developed initially when analysis for more specific radionuclides were significantly more expensive and difficult. Radon in water by liquid scintillation costs about $30, about the same cost as gross alpha or gross beta. Radium costs $140, and uranium $90 per sample. By restricting the analytical work to radon in groundwater, we were able to screen a larger number of samples in wider hydrogeologic settings, and thus are in a better position to evaluate where and in which units naturally occurring radionuclides might be a problem. In a gross alpha or gross beta analysis, the water is evaporated to dryness on a planchet, and the total alpha or beta radiation measured. This technique was used on a number of samples previously analyzed and compared to radon values for the same wells. These techniques provide no clear relationship between gross radioactivity and a specific radionuclide such as radon (figure 1 and 2; appendix 3).

^{226}Ra is produced from the decay of ^{238}U, whereas ^{228}Ra is produced from the decay of ^{232}Th. Based on evaluations performed for this project on previously analyzed data, there is very poor correlation between direct radium analysis and radon (figure 3 and 4), or between uranium and radon in groundwater (figure 5; appendix 3).

As a result of this evaluation and the recognition that the U.S. Environmental Protection Agency has proposed a standard for radon in drinking water, we concluded that a cost effective study should concentrate on radon rather than on a much wider spectrum of radionuclides.

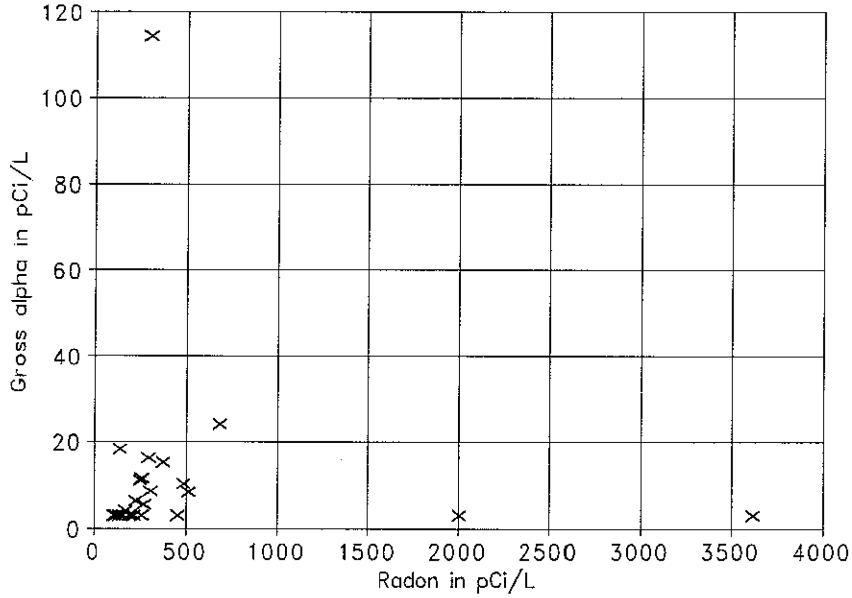

Figure 1. Comparison of gross alpha to radon in groundwater.

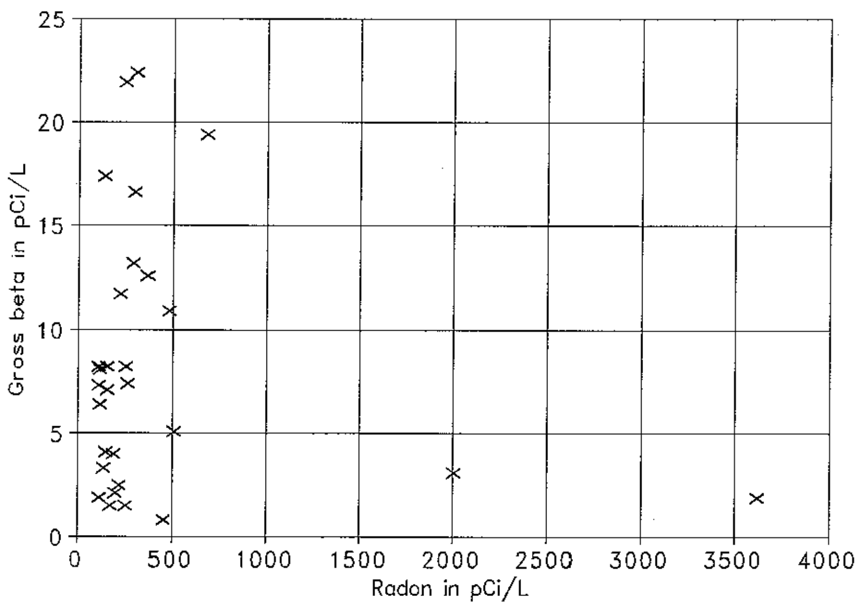

Figure 2. Comparison of gross beta to radon in groundwater.

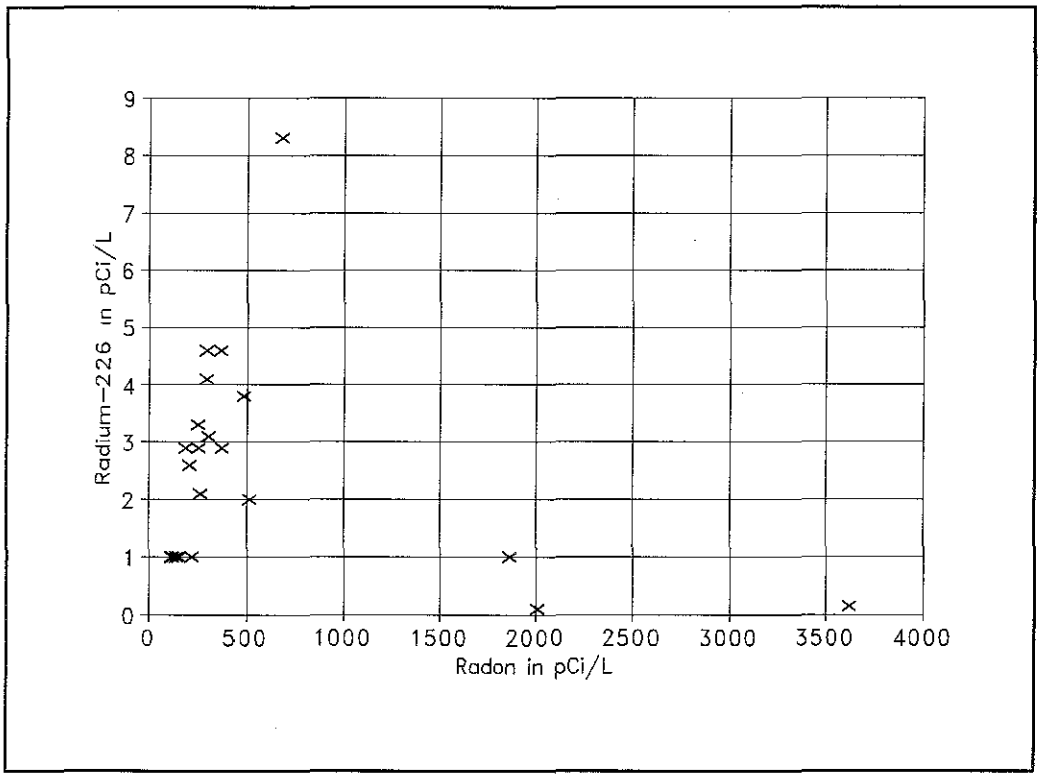

Figure 3. Comparison of ^{226}Ra to radon in groundwater.

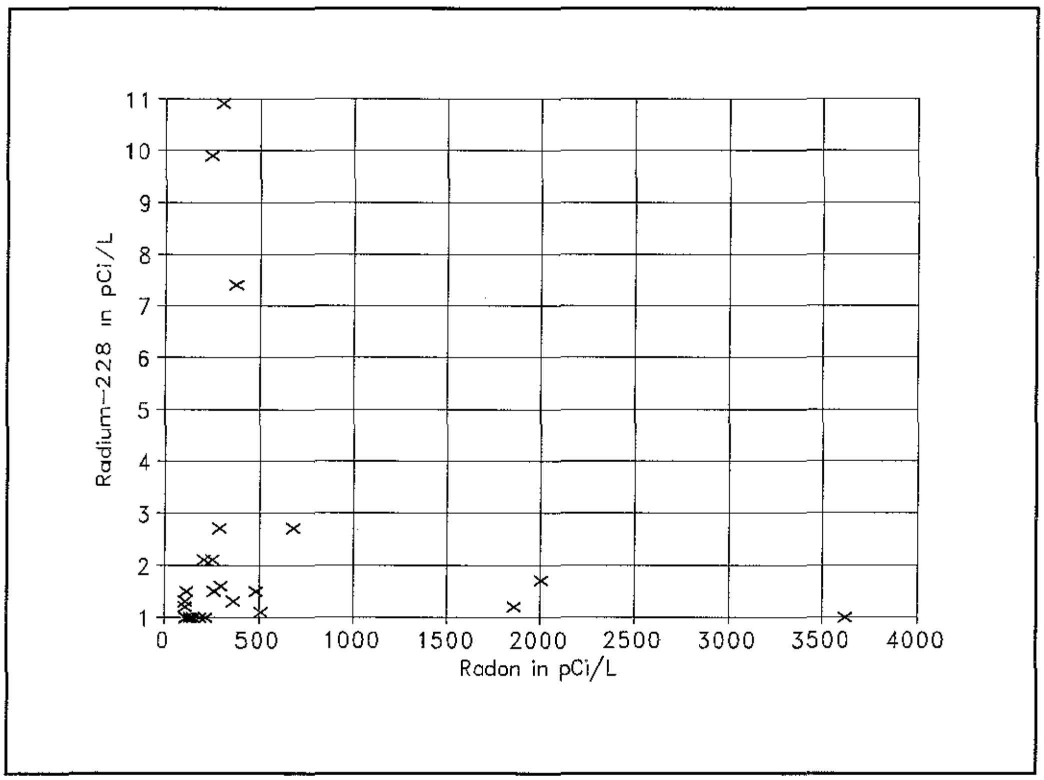

Figure 4. Comparison of ^{228}Ra to radon in groundwater.

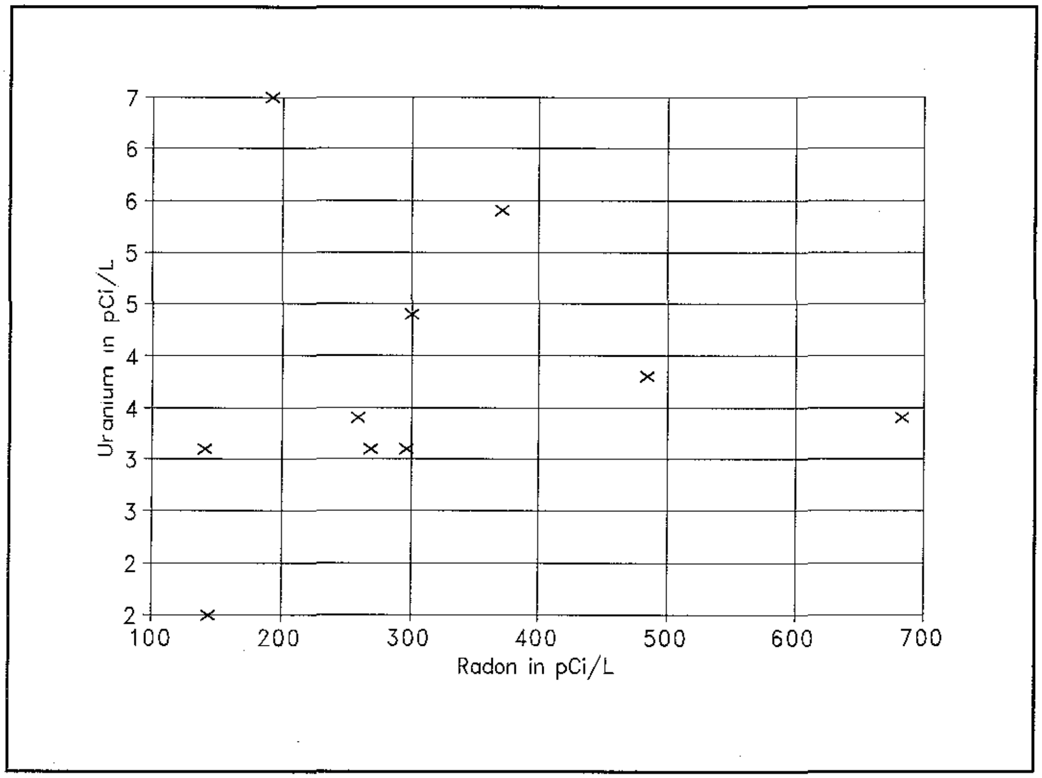

Figure 5. **Comparison of uranium to radon in groundwater.**

METHODOLOGY - Laboratory Comparison

Radon in water test kits were purchased from the State Laboratory of Hygiene, and from AirChek of North Carolina (appendix 1 describes the sampling procedure used; appendices 2 and 3 present the data). In addition, several free kits were provided by Wisconsin Radiologic Laboratories (WRL). AirChek and WRL market their scintillation analytical system for about $15 per sample; the State Laboratory of Hygiene markets theirs for $33. All three laboratories are EPA certified. Because of the price differential of the kits, we wished to determine whether the less expensive kits would return useable data, and thus permit a more cost effective sampling strategy. Figure 6 and 7 compares the State Laboratory of Hygiene, AirChek and Wisconsin Radiological Laboratories data acquired for this project.

In general, both AirChek and WRL test results fall below the State Laboratory of Hygiene results. Several possibilities present themselves to explain these data.

It is exceeding difficult to increase the radon concentration in a water sample; whereas it is relatively easy to decrease the apparent concentration. The distribution coefficient of radon in air to radon in water is about 10,000 to 1. As a result, any small air bubble in the sample vial effectively contains most of the radon in the sample. Some of the samples, in fact, out-gassed and contained small bubbles. This came about for one of two reasons: excess

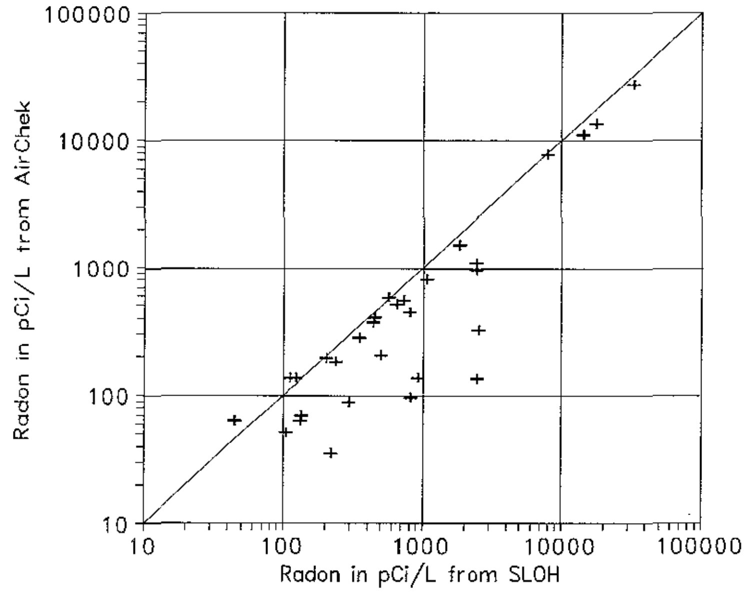

Figure 6. Comparison of radon in groundwater by AirChek and State Laboratory of Hygiene. The diagonal line is the 1:1 correlation line.

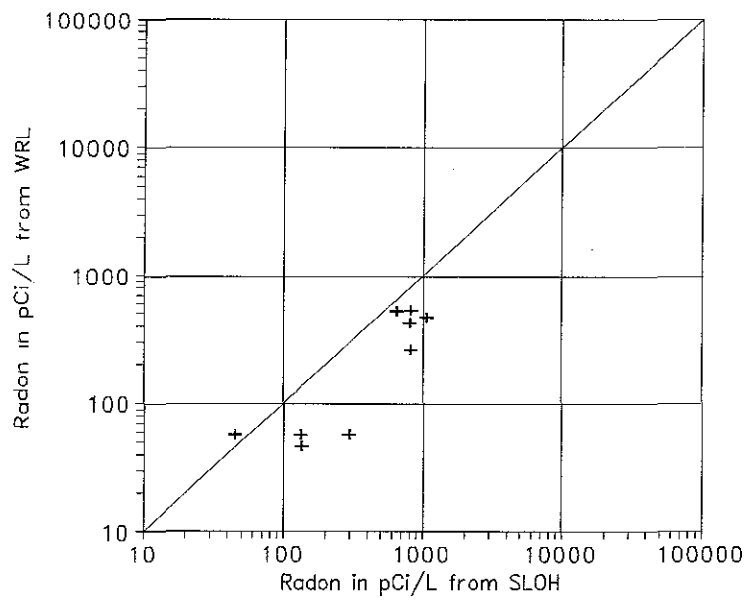

Figure 7. Comparison of radon in groundwater by WRL and State Laboratory of Hygiene. The diagonal lines is the 1:1 correlation line.

carbonate of natural groundwater or warming of the groundwater from ambient to air temperature resulting in out-gassing. When noticed, the sample was not analyzed but was resampled if possible. Results of samples sent to AirChek and WRL did not report whether or not air bubbles had formed.

There may be small leakage of radon from around the screw cap on the bottle, and aircraft depressurization for samples mailed to North Carolina (AirChek) may have resulted in a loss of radon from the vial. Such loss mechanism does not explain the low WRL samples, as the laboratory is located in Madison, and samples were analyzed there in the same timely fashion that State Laboratory of Hygiene samples were.

There may be a systematic bias, or efficiency over-estimate in the State Laboratory, resulting in falsely elevated concentrations. Intra-laboratory checks with National Bureau of Standards traceable standards at the State Laboratory suggest that such is not the case.

We believe that sample vial leakage may in fact be the explanation for the lower values reported by AirChek and WRL.

As a result, we recommend using the State Laboratory, in as much as the higher reported values lead one to err on the side of conservatism, and over-estimate the radon in water risk. Further discussion is limited to results from the State Laboratory of Hygiene.

WELL SELECTION

A preliminary meeting was held between the Geological and Natural History Survey and the Wisconsin Department of Natural Resources. At that meeting it was decided that sampling be directed toward wells with well defined construction reports. Four areas in Wisconsin under study by the Geological and Natural History Survey for other groundwater studies were chosen for radon sampling. The four area studies by the Geological and Natural History Survey are: Door County where deep monitoring wells were drilled into Silurian dolomite to evaluate fracture hydrology; Black Earth Watershed to evaluate water use and recharge in developing suburban Madison in Ordovician dolomite; Feis Feeder Creek recharge area south of Mount Horeb, Dane County to monitor and evaluate application of herbicides under field conditions in Ordovician dolomite; and Shullsburg where replacement wells were constructed when the original wells were found to be impacted by mine water in Ordovician sandstone. Each of these four areas have monitoring or domestic-use wells constructed to Department standards and have good construction reports available or geological and geophysical logs prepared by the Geological and Natural History Survey (figure 8). In addition, test kits were provided to the North-central District of the Department of Natural Resources in order to extend and refine existent sampling for radon, and test kits were provided to the Central Groundwater Center to initiate radon sampling east of Stevens Point in the Waupaca area.

In addition, a few selected wells elsewhere in Wisconsin were chosen to reflect unique hydrogeologic settings, and include water from Crystal Cave, Pierce County, where heavily developed karst is present.

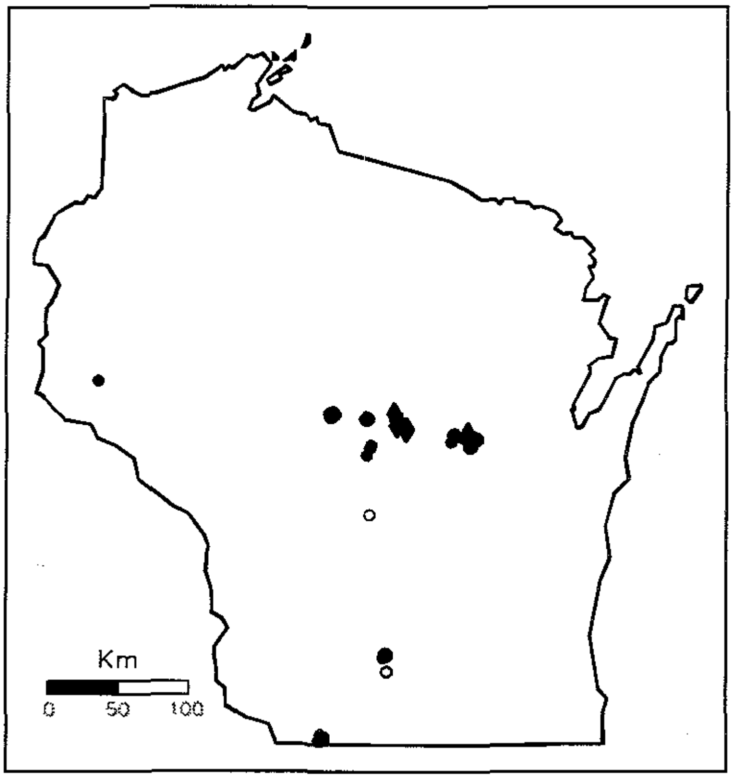

Figure 8. Simplified base map of Wisconsin showing distribution of well chosen to evaluate radon in groundwater. open cirlces below 300 pCi/L; solid between 300 and 40,000; diamond above 40,000.

Radon in water was determined for 89 samples from central, southern and northeastern Wisconsin localities. The only geologic unit tested that uniformly do not exhibit elevated radon concentration is the St. Peter sandstone. This is a major aquifer in southern Wisconsin. The wells in the Shullsburg area produce from the St. Peter. Water from dolomite wells in Dane, Door and Pierce County all have radon around 1000 pCi/L. Exceptions are spring and shallow wells in dolomite in western Dane county. Based on other geochemical data, these well have a short residence time, and the water may well be short-lived groundwater from rainwater rather than deep, aged groundwater.

We believe the elevated radon in dolomite results from a multi-stage geochemical model, much like was has been found for radon in air in carbonate terranes. Small amounts of uranium in groundwater is precipitated as uranyl carbonate along joints. As a result, although the amount of radionuclides is small, all is labile and available to move into the water column. Exceedingly high radon concentrations, however, are found only in granite or in surficial material derived from granite.

DISCUSSION

Because EPA is proposing a low radon concentration in water as a standard (300 pCi/L), available data suggest that water supplies every where in Wisconsin can exceed that value, however in southern and eastern Wisconsin water supplies will exceed the proposed standard by about 5 times, whereas in northern Wisconsin, water supplies may exceed that standard by several orders of magnitude.

Recommendations

Analysis of groundwater for radon should continue, and areas in eastern Wisconsin having granite bedrock geology, or surficial material derived from granite should be evaluated.

A more comprehensive evaluation of existing data should be undertaken to more fully evaluate the source of radon in groundwater in order to design well construction to minimize radionuclide contamination.

REFERENCES

Fitzgerald, Charles, 1990, Naturally occurring radionuclides in groundwater of North Central Wisconsin: Wisconsin Department of Natural Resources North-central District Report.

Graves, Barbara, editor, 1987, Radon, radium, and other radioactivity in ground water, Proceedings of the NWWA Conference April 7-9, 1987, Somerset, New Jersey: Lewis Publishers, Chelsea, Michigan, 546 p.

Gundersen, L.C.S. and Wanty, R.B., editors, 1993, Field studies of radon in rocks, soils, and water, C.K. Smoley, Boca Raton, Florida, 334 p.

Hahn, Norman, 1990, Disposal of radium from drinking water treatment, *in* C.R. Cothern and P.A., Rebers, eds., Radon, radium and uranium in drinking water, Lewis Publishers, Chelsea, Michigan, p. 249-267.

Appendix 1- Collection procedures for radon in water (from Wisconsin State Laboratory of Hygiene.

State Laboratory of Hygiene
Radiation Protection Unit
Madison, WI 53706
(608) 263-4766

IMPORTANT: READ ALL INSTRUCTIONS ON REVERSE SIDE.

Please type or print clearly and be sure that all spaces are filled in. Your test cannot be processed unless complete information is provided.

Send results to:

Name: ______________________

Address: ______________________

City, State, Zip: ______________________

Daytime telephone: ______________________

Test site (if different from above):

Address: ______________________

City, State, Zip: ______________________

Collection Information

Collection Date: ____ – ____ – ____

Collection Time: ____ : ____ AM or PM (circle one)

Do not write below this line

Date Received: ______________ Sample Number: ______________

COLLECTION PROCEDURES FOR RADON IN WATER

In order to insure accurate results, it is important that proper sampling procedures are followed. *Please read all directions before beginning test!*

Samples should be collected on **Sunday, Monday** or **Tuesday**, and sent to the laboratory as soon as possible.

For best results the sample should be collected after the pump has cycled several times after doing the wash or taking a shower for example) The sample should be collected as close to the source as possible (the holding tank would be ideal; the nearest bathroom, laundry, or kitchen faucet is acceptable).

1. The radon test kit should contain a vial with a two-piece cap
2. You will also need a bowl or other container that is at least three inches deep.
3. If the sampling faucet contains an aerator, remove it.
4. Run the water until cold. (If sound from pump cycling is noticeable, begin to collect the sample about a minute after the pump starts.)
5. Remove the cap from the sample vial, making sure that the liner does not fall out. If the liner does fall out, replace it in the cap so the brown rubber side of the liner is visible when the vial is capped.
6. Place the bowl (*see step 2*) directly under the faucet and fill, being careful to keep the spigot opening under water after the bowl begins to fill.
7. Fill the bowl to the point of overflowing. Continue adding water, with the opening of the faucet still below the water level, for about a minute.
8. Submerge the vial in the bowl, open side up, until it fills. At this point, set the bowl down, and put the cap in the water, open end up. While still underwater, replace the cap. Tighten firmly, but do not over-tighten.
9. Lift the closed vial out of the water. Turn the vial upside down and check closely for air bubbles. If there is an air bubble, empty the vial and the bowl and start again at step 6.

   Note: Radon, a gas, prefers air to water. With even a small bubble in the vial, some of the radon leaves the water, leaving less radon in the water to measure.
10. Complete the form found on the reverse side of this sheet, making sure to **include the collection time** as well as the date.
11. Place the vial, this sheet (with the reverse side completed), and a check for $37.50 (payable to the State Laboratory of Hygiene) in the styrofoam mailer. The check and this sheet should be enclosed in the plastic bag provided. Secure the mailer with tape and attach the mailing label provided.
12. Ship as soon as possible after the vial is filled to the State Laboratory of Hygiene via UPS or the Postal System (first class).

    Caution: **Do not leave unattended in mailbox during cold weather. The water-filled vial can freeze and break.**

COMPLETE REVERSE SIDE

Appendix 2. Data for wells sampled

Wisconsin Unique Well No.	Radon Concentration (pCi/L)	Location 1/4, Sec., Town, Range	Aquifer or aquifer material	Collected by date
FC073	726.	NW,Sec.20,T.05N.,09E	St. Peter sandstone	K. Bradbury 11/06/91
DH736	844.	NW,Sec.20,T.05N.,09E	St. Peter sandstone	K. Bradbury 11/06/91
ES977	122.	SW,Sec.31,T.29N.,27E	Silurian dolomite	K. Bradbury 11/05/91
EI342	920.	SE,Sec.02,T.28N.,26E	Silurian dolomite	K. Bradbury 11/05/91
ES977	< 112.	SW,Sec.31,T.29N.,26E	Silurian dolomite	K. Bradbury 11/05/91
ES973	498.	NW,Sec.28,T.36N.,14W	sand and gravel	M. Muldoon 11/21/91
ES972	445.	NW,Sec.28,T.36N.,14W	sand and gravel	M. Muldoon 11/21/91
ES975	< 105.	NE,Sec.07,T.34N.,17W	sand and gravel	M. Muldoon 11/21/91
ES974	350.	NE,Sec.07,T.34N.,17W	Not given	M. Muldoon 11/21/91
ES976	237.	SW,Sec.24,T.36N.,19W	sand and gravel	M. Muldoon 11/21/91
EZ188	< 2407.	SE,Sec.17,T.23N.,13E	outwash	G. Kraft 11/20/91
EZ215	< 2444.	SE,Sec.33,T.23N.,13E	outwash	G. Kraft 11/20/91
EZ156	< 2411.	SW,Sec.05,T.23N.,12E	outwash	G. Kraft 11/20/91
ES990	442.	NE,Sec.14,T.24N.,08E	outwash	G. Kraft 12/03/91
EZ213	7914.	SE,Sec.14,T.23N.,13E	granite	G. Kraft 11/20/91
EZ190	14277.	NE,Sec.05,T.23N.,13E	granite	G. Kraft 11/20/91
EZ154	564.	NW,Sec.19,T.23N.,12E	granite	G. Kraft 12/04/91
EZ225	< 2541.	NW,Sec.13,T.23N.,13E	granite	G. Kraft 11/20/91
EZ173	17743.	SW,Sec.05,T.23N.,13E	granite	G. Kraft 11/20/91
EZ168	498.	SE,Sec.11,T.23N.,12E	outwash	G. Kraft 12/03/91

Wisconsin Unique Well No.	Radon Concentration (pCi/L)	Location 1/4, Sec., Town, Range	Aquifer or aquifer material	Collected by date
FG852	106.	SE,Sec.21,T.01N.,02E	St. Peter sandstone	T. Evans 01/07/92
AQ801	247.	SW,Sec.21,T.06N.,07E	dolomite	W. Hall 02/10/92
AQ833	181.	SW,Sec.21,T.06N.,07E	Prairie du Chien	W. Hall 02/10/92
AQ834	< 109.	SW,Sec.21,T.06N.,07E	Prairie du Chien	W. Hall 02/10/92
AQ835	< 110.	SW,Sec.21,T.06N.,07E	Prairie du Chien	W. Hall 02/10/92
EZ602	56885.	SW,Sec.17,T.24N.,08E	Not given	F. Bailey 03/18/92
EZ601	14791.	NE,Sec.25,T.24N.,08E	granite	F. Bailey 03/18/92
ES658	32644.	SW,Sec.25,T.24N.,08E	granite	F. Bailey 03/24/92
ES659	1815.	SE,Sec.01,T.24N.,07E	granite	F. Bailey 03/24/92
EZ660	15282.	SE,Sec.25,T.24N.,08E	Not given	F. Bailey 04/06/92
EZ603	9444.	SE,Sec.25,T.24N.,08E	Not given	F. Bailey 04/06/92
BQ216	574.	NE,Sec.25,T.24N.,03E	Not given	F. Bailey 04/06/92
EF565	1647.	NW,Sec.01,T.26N.,09E	Not given	F. Bailey 05/04/92
EF564	1587.	NE,Sec.36,T.26N.,09E	Not given	F. Bailey 06/01/92
ES983	297.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92
ES981	813.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92
ES982	45.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92
FG025	1057.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92
ES979	820.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92

Wisconsin Unique Well No.	Radon Concentration (pCi/L)	Location 1/4, Sec., Town, Range	Aquifer or aquifer material	Collected by date
ES980	133.	SW,Sec.31,T.29N.,27E	Silurian dolomite	06/04/92
EC897	135.	SE,Sec.12,T.08N.,08E	Horicon Fm.	J. Levy 06/11/92
EC898	204.	SE,Sec.12,T.08N.,08E	Horicon Fm.	J. Levy 06/11/92
CK227	646.	SE,Sec.12,T.08N.,08E	sandstone	J. Levy 06/11/92
EC823		SE,Sec.12,T.08N.,08E	Not given	J. Levy
FG857	63.	NE,Sec.22,T.01N.,02E	St. Peter sandstone	T. Evans
FG856	98.	NE,Sec.15,T.01N.,02E	St. Peter sandstone	T. Evans
FG853	102.	SW,Sec.28,T.01N.,02E	St. Peter sandstone	T. Evans
FG855	111.	NE,Sec.28,T.01N.,02E	St. Peter sandstone	T. Evans
FG854	520.	NE,Sec.29,T.01N.,02E	St. Peter sandstone	T. Evans
FG852	141.	SE,Sec.21,T.01N.,02E	St. Peter sandstone	T. Evans 04/22/93
FG024	163.	NE,Sec.27,T.01N.,02E	St. Peter sandstone	T. Evans
FG025	138.	SW,Sec.22,T.01N.,02E	St. Peter sandstone	T. Evans
FG860	62.	NE,Sec.26,T.01N.,02E	St. Peter sandstone	T. Evans
FG859	221.	SW,Sec.14,T.01N.,02E	Galena/Pville	T. Evans
FG858	68.	SW,Sec.14,T.01N.,02E	St. Peter sandstone	T. Evans
FG851	150.	SE,Sec.09,T.01N.,02E	St. Peter sandstone	T. Evans

Wisconsin Unique Well No.	Radon Concentration (pCi/L)	Location 1/4, Sec., Town, Range	Aquifer or aquifer material	Collected by date
FC500	4230.	NE,Sec.36,T.25N.,05E	granite	F. Bailey 08/27/92
FC532	13600.	SW,Sec.19,T.25N.,08E	granite	F. Bailey 08/31/92
CH280	2900.	NW,Sec.30,T.23N.,05E	granite	F. Bailey 09/24/92
EZ584	900.	SE,Sec.24,T.22N.,05E	granite	F. Bailey 09/08/92
AW979	130.	SW,Sec.31,T.18N.,06E	sandstone	F. Bailey 09/08/92
CA363	4500.	NE,Sec.21,T.25N.,03E	granite	F. Bailey 09/08/92
CA364	3200.	NE,Sec.21,T.25N.,03E	granite	F. Bailey 09/08/92
CE211	51700.	SW,Sec.17,T.24N.,08E	granite	F. Bailey 09/24/92
DR177	38200.	SE,Sec.17,T.24N.,08E	granite	F. Bailey 09/24/92
FC542	32500.	NW,Sec.17,T.24N.,08E	granite	F. Bailey 09/24/92
AR043	4700.	NW,Sec.05,T.24N.,08E	Not given	F. Bailey 09/24/92
AP448	905.	NE,Sec.32,T.23N.,06E	granite	F. Bailey 09/24/92
FC540	3600.	NW,Sec.29,T.25N.,03E	granite	E. Brasch 09/28/92
FC538	5900.	SW,Sec.20,T.25N.,03E	granite	F. Bailey 09/28/92
FG023	430.	SW,Sec.01,T.24N.,16E	Mt. Simon sandstone	W. Batten 10/07/92
FG023	290.	SW,Sec.01,T.24N.,16E	Mt. Simon sandstone	W. Batten 10/07/92
	740.	SW,Sec.01,T.24N.,16E	Not given	J. Butler 10/08/92
FF001 Amann	788.	NW,Sec.17,T.07N.,07E	spring in sandstone	Mary Ann
FF002 Amann	422.	SE,Sec.08,T.07N.,07E	spring in sandstone	Mary Ann
FF003 Amann	742.	SE,Sec.08,T.07N.,07E	spring in sandstone	Mary Ann

Wisconsin Unique Well No.	Radon Concentration (pCi/L)	Location 1/4, Sec., Town, Range	Aquifer or aquifer material	Collected by date
FF004	331.	NE,Sec.17,T.07N.,07E	spring in sandstone	Mary Ann Amann
FF005	580.	NE,Sec.17,T.07N.,07E	spring in sandstone	Mary Ann Amann
FF006	678.	NE,Sec.08,T.07N.,07E	alluvium	Mary Ann Amann
FF007	393.	NE,Sec.08,T.07N.,07E	alluvium	Mary Ann Amann
FF008	1248.	SE,Sec.17,T.07N.,07E	dolomite	Mary Ann Amann
FF009	105.	SE,Sec.19,T.07N.,07E	dolomite	Mary Ann Amann
FF010	566.	NW,Sec.16,T.07N.,07E	dolomite	Mary Ann Amann
FF011	301.	NE,Sec.16,T.07N.,07E	dolomite	Mary Ann Amann
FG026	800.	SW,Sec.07,T.27N.,15W	dolomite	B. Cunningham 01/05/93
CR699	< 100.	NW,Sec.05,T.22N.,06E	granite	F. Bailey 09/03/92
FG024	< 270.	SE,Sec.23,T.15N.,17E	Sinnipee dolomite	

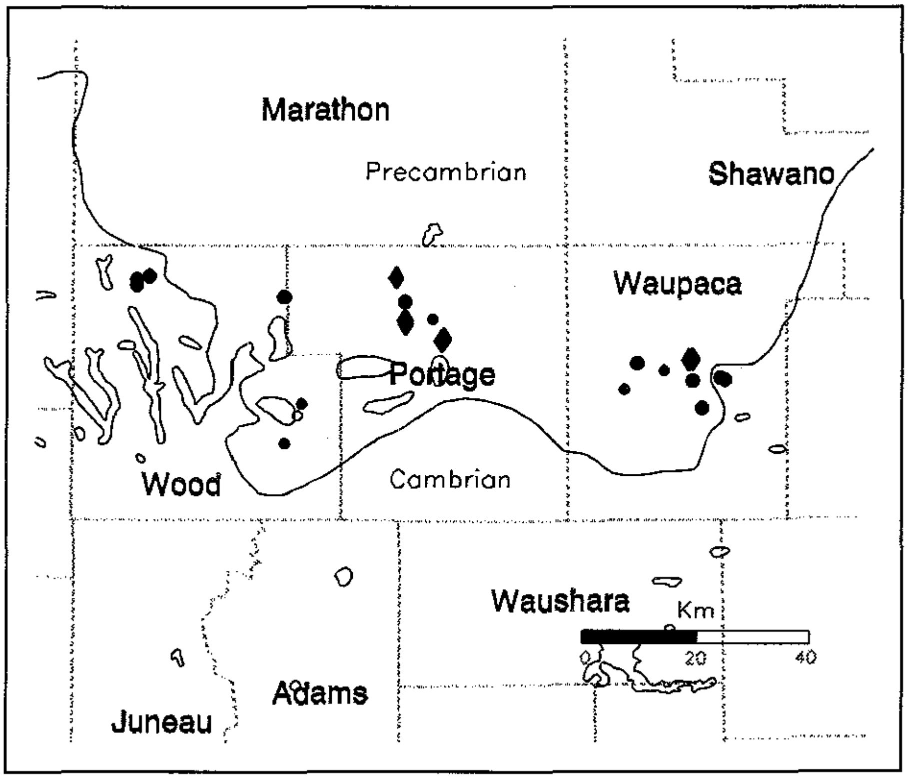

Figure 9. Distribution of samples in central Wisconsin. Solid circles between 300 and 40,000 pCi/L; diamonds above 40,000.

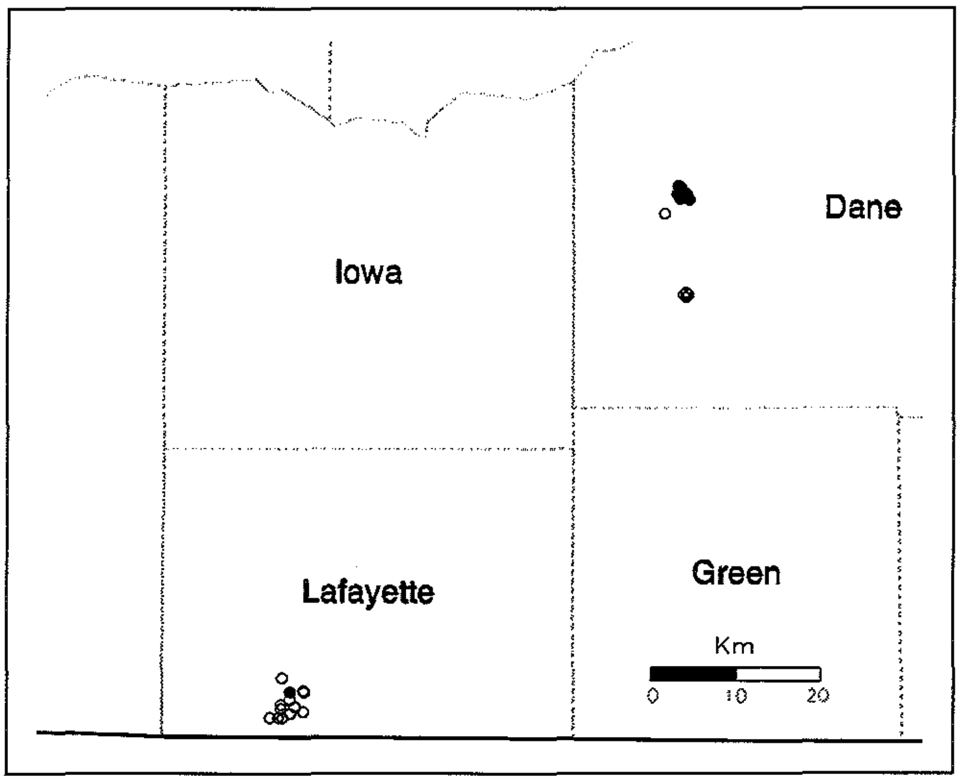

Figure 10. Distribution of samples in southern Wisconsin. Open circles below 300 pCi/L; solid circles 300 to 2000 pCi/L

Appendix 3 - Interlaboratory comparison of radon in water

Wisconsin Unique Well ID	State Laboratory of Hygiene	AirChek	Wisconsin Radiological Laboratory
FC-073	726.	546.	
ES-977	122.	<136.	
EI-342	920.	<137.	
ES-977	<112.	<136.	
ES-973	498.	203.	
ES-972	445.	407.	
ES-975	<105.	<51.	
ES-974	350.	282.	
ES-976	237.	181.	
EZ-188	<2407.	1070.	
EZ-215	<2444.	133.	
EZ-156	<2411.	945.	
ES-990	442.	372.	
EZ-213	7914.	7752.	
EZ-190	14277.	11026.	
EZ-154	564.	584.	
EZ-225	<2541.	322.	
EZ-173	17743.	13382.	
ES658	32644.	27166.	
ES659	1815.	1489.	
	297.	88.	<56.4
	813.		261.5
	45.	<63.	<56.4
	1057.	805.	463.7
	820.	96.	524.3
	133.	<63.	<56.4
EC897	135.	69.	<45.9
EC898	204.	194.	
CK227	646.	515.	517.5
	221.	35.	
	800.	443.	423.