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IOWA SURVEY OF WATERBORNE ^{222}RN CONCENTRATIONS IN PRIVATE WELLS

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ABSTRACT

The major objective of the survey was to describe the distribution of waterborne ^{222}Rn concentrations in Iowa's private well-water supplies. Well-water samples were obtained and analyzed for ^{222}Rn from a random sample of 352 Iowa wells. The well-water ^{222}Rn concentrations for the well sites were lognormally distributed and ranged from background concentrations to 2,342 pCi L^{-1} (87 Bq L^{-1}), with a median value of 311 pCi L^{-1} (12 Bq $^{-1}$). The arithmetic mean ^{222}Rn concentration for the sites was 429 pCi L^{-1} ± 364 pCi L-1 (16 Bq l^{-1} ± 13 B L^{-1}). The geometric mean ^{222}Rn concentration was 318 pCi L^{-1} with a geometric standard deviation of 2.2 pCi L^{-1} (GM = 12 Bq L^{-1}, GSD = 81 mBq L^{-1}). Over half of the samples (52%) exceeded 300 pCi L^{-1} (11 Bq L^{-1}). Both well depth and indoor air ^{222}Rn screening levels correlated with waterborne ^{222}Rn concentrations; however, these correlations had very little predictive value. Glacial drift aquifers tended to have the highest ^{222}Rn concentrations, although there was significant variance of ^{222}Rn concentrations within all the aquifer classifications. In light of the estimate that 10,000 pCi L^{-1} (370 Bq L^{-1}) of ^{222}Rn in water may lead to 1 pCi L^{-1} (37 mBq L^{-1}) in indoor air, the contribution of well-water derived indoor air ^{222}Rn is minimal compared to ground sources in Iowa.

INTRODUCTION

The potential for high ^{222}Rn concentrations in private well-water is a particular concern in Iowa where 745,000 rural residents use groundwater from private supplies as their primary water supply. This potential waterborne ^{222}Rn source is also of special significance in view of the discovery that out of the 38 U.S. states tested by the U.S. Environmental Protection Agency (EPA)-state cooperative program, Iowa had both the highest mean ^{222}Rn level and the highest percentage of homes with indoor air screening measurements > 4 pCi L^{-1} (Alexander et al. 1992). A recent indoor air ^{222}Rn screening survey of 582 rural households in Iowa, which use well-water as their primary drinking source, confirmed the findings of the EPA-Iowa Department of Public Health cooperative program survey (Field et al. 1993). Because of the above concerns, we performed a waterborne ^{222}Rn survey of private wells in rural areas. The major objective of the survey was to describe the distribution of waterborne ^{222}Rn concentrations in Iowa's private well-water supplies.

MATERIALS AND METHODS

A waterborne ^{222}Rn survey of private Iowa wells was performed between August 1991 and November 1991, using the sampling frame from the Iowa Statewide Rural (SWRL) Well Water Survey, a population density-stratified, geographically systematic sampling grid based on latitude and longitude intersections (Hallberg et al. 1990). The SWRL survey sampling frame targets rural residents of Iowa who use well water as their primary drinking source. Detailed information concerning the SWRL survey sampling frame and SWRL survey population demographics are presented elsewhere (Hallberg et al. 1990).

During August 1991, 566 SWRL survey participants were sent a ^{222}Rn sampling kit containing two 20 ml. glass vials with teflon-rubber plenum tops along with a detailed instruction sheet, a short questionnaire and a pre-addressed postage paid return envelope. The instructions directed the participants to collect water from a bathroom tap within the home after both the tap aerator was removed and the water was allowed to run for 10 minutes. The participants were directed to place the collection vial approximately one inch below the faucet, while filling the vial to the brim. The instructions clearly stated that the cap should be quickly and securely placed on the vial and that the filled bottle should be inverted to insure that there were no air bubbles in the vial. If there were bubbles in the vial, the participants were instructed to repeat the collection procedure.

The questionnaire which accompanied the collection kit included questions regarding collection site, collection time and factors that may reduce radon concentration between well and faucet, such as the use of a charcoal filtration unit. The participants were requested to deposit the samples in the mail within 24 hours of sampling. A pilot study of this sampling technique found good agreement (Spearman Rank Order Correlation Coefficient = 0.969, $p<0.005$) with results from water concurrently sampled at the outside tap of the same home by trained personnel using an established Environmental Protection Agency protocol (U.S. EPA 1978). Additional information concerning the sampling technique and its validation can be found elsewhere (Field 1993).

Upon receipt at the University, the samples were inspected for air bubbles and the questionnaires were checked for completeness. Immediately after removing the vial's plenum top, ten mls. of water was drawn by syringe from the bottom of the collection vial and injected under 10 ml. of an oil based liquid scintillation fluid contained in a liquid scintillation vial. The liquid scintillation vial was capped and shaken for 10 seconds so that the ^{222}Rn could move into the scintillation fluid. The samples were allowed to elute into the scintillation fluid for a minimum of 4 hours. Each sample was then counted for one hour on a Packard Instruments Company Model 1900TR Liquid Scintillation Counter with blanks and a set of ^{222}Rn standards obtained form the EPA's Environmental Monitoring Systems Laboratory in Las Vegas.

Waterborne ^{222}Rn samples that met any of the following exclusion criteria were eliminated from the summary data presented in this paper: water samples which have undergone charcoal filtration, water samples with inverted vial septa and water samples with significant air bubbles. Supplemental details concerning analysis of waterborne ^{222}Rn and data reduction are available elsewhere (Field 1993). The wells' depth, longitude, latitude, casing depth and aquifer type were obtained by the Iowa Department of Natural Resources (Hallberg et al. 1990).

RESULTS AND DISCUSSION

Satisfactory samples for inclusion in the summary SWRL survey ^{222}Rn data set were obtained from 352 sites. The ^{222}Rn content of the samples ranged from 23 pCi L^{-1} (852 mBq L^{-1}) to 2,342 pCi L-1 (87 Bq L^{-1}), with a median value of 311 pCi L^{-1} (12 Bq L^{-1}). The arithmetic mean waterborne ^{222}Rn concentration for the 352 sites was 429 pCi L^{-1} ± 364 pCi L^{-1} (16 Bq L^{-1} ± 13 Bq L^{-1}). The geometric mean ^{222}Rn concentration was 318 pCi L^{-1} with a geometric standard deviation of 2.2 pCi L^{-1} (GM = 12 Bq L^{-1}, GSD = 81 mBq L^{-1}) (Fig. 1). This finding is in agreement with analyses recently performed on the raw water at 153 public water supplies in Iowa which found 52% of the samples exceeded the EPA's proposed ^{222}Rn public drinking water standard of 300 pCi L^{-1} (Kelly and Mehrhoff 1993).

Aquifer Type

The 352 collection sites were comprised of 11 distinct aquifer types. The mean ^{222}Rn concentrations and mean well depth by aquifer type are presented in Table 1. A one way analysis of variance test failed to detect a significant difference in the ln transformed ^{222}Rn concentrations ($p = 0.124$) among the bedrock aquifer types (Cretacious, Pennsylvanian, Mississippian, Silurian, Devonian, Ordovician and Cambrian). However, a significant difference was found among the various unconsolidated aquifer types (Alluvial and Pleistocene groupings) using a Kruskal-Wallis one way analysis of variance on ranks ($p = 0.042$). The non-parametric Kruskal-Wallis one way analysis of variance was used because the ln transformed data for the unconsolidated aquifer types failed to exhibit equal variances according to the Levene Median test ($p = 0.017$). Dunn's all pairwise multiple comparison test isolated significant differences between the median values of the Alluvial and Pleistocene undifferentiated aquifer types. The higher waterborne ^{222}Rn concentrations noted in the Pleistocene undifferentiated aquifer type can be ascribed to the fine grained glacial drift. Figures 3-12 present the relative ^{222}Rn concentrations by aquifer type.

Well Depth

The mean well depth for the various aquifer types is presented on Table 1. A linear regression revealed that the ln ^{222}Rn concentrations for the 352 sites tended to decrease as the ln well-depth increased ($p<0.001$, $r = 0.226$).

This finding can most likely be attributed to the higher ^{222}Rn concentrations noted in the shallower Pleistocene and Pleistocene undifferentiated well types. However, a similar trend was noted for the Mississippian aquifer type ($p = 0.028$, $r = 0.344$).

Screening Radon Measurements

^{222}Rn air screening measurements (Field et al. 1993) could be compared with ^{222}Rn well-water concentrations for 321 SWRL survey sites. A linear regression of these two data sets found that the ln of the air ^{222}Rn concentrations tended to increase as the ln of the ^{222}Rn well-water concentration increased ($p = 0.016$, $r = 0.134$). This trend was not noted in any of the specific aquifer subsets.

CONCLUSION

^{222}Rn concentrations in 352 randomly selected private Iowa wells exhibited a geometric mean ^{222}Rn concentration of 318 pCi L^{-1} with a geometric standard deviation of 2.2 pCi L^{-1} (GM = 12 Bq L^{-1}, GSD = 81 mBq L^{-1}). The ^{222}Rn concentrations were lognormally distributed, with 52% of the samples exceeding 300 pCi L^{-1} (11 Bq L^{-1}). Both well depth and indoor ^{222}Rn screening levels correlated with waterborne ^{222}Rn concentrations; however, the strength of the linear relationship was not very great. Glacial drift aquifers tended to have the highest ^{222}Rn concentrations, although there was significant variance of ^{222}Rn concentrations within all the aquifer classifications. In light of the estimate that 10,000 pCi L^{-1} (370 Bq L^{-1}) of ^{222}Rn in water leads to 1 pCi L^{-1} (37 mBq L^{-1}) of ^{222}Rn in indoor air, the contribution of well-water derived indoor air ^{222}Rn is minimal compared to ground sources.

REFERENCES

Alexander, B.; Rodman, N.; White, S.B.; Phillips, J. Summary of regional estimates of indoor screening measurements of ^{222}Rn. In: Proceedings of The 1992 International Symposium on Radon And Radon Reduction Technology, Minneapolis, MN: U.S. Environmental Protection Agency; 1992.

Field, R.W. Iowa private well-water ^{222}Rn survey and evaluation of waterborne ^{222}Rn sampling techniques, Iowa City, Iowa: University of Iowa; 1993. PhD. Dissertaion.

Field, R.W.; Kross, B.C.; Weih, L.M.B.; Vust, L.J.; Nicholson, H.F. Factors associated with elevated ^{222}Rn levels in Iowa. Health Phys. 65(2):178-184; 1993.

Hallberg, G.R.; Kross, B.C.; Libra, R.D.; Burmeister, L.F.; Weih, L.M.B.; Lynch, C.F.; Bruner, D.R.; Lewis, M.O.; Cherryholmes, K.L.; Johnson, J.K..; Culp, M.A. The Iowa State-Wide Rural Well-Water Survey Design Report: A Systematic Sampling of Domestic Drinking Water Quality, Technical Information Series 17, Iowa Department of Natural Resources; 1990.

Kelly, R.; Mehrhoff, M. Radon-222 in the source and finished water of selected public water supplies in Iowa, Research report No. 93-1, University of Iowa Hygienic Laboratory, Iowa City, Iowa; 1993.

U.S. Environmental Protection Agency, Radon in water sampling program, EPA/EERF-Manual-78-1, Eastern Environmental Radiation Facility, Montgomery, AL; 1978.

Table 1. Mean ^{222}Rn concentration and well depth for the various aquifer types samples.

Aquifer Type	^{222}Rn Concentration pCi L^{-1} (SD)		Geometric Mean ^{222}Rn pCi L^{-1} (GSD)		(N)	Aquifer Depth ft (SD)	
Alluvial	359	(324)	267	(2.2)	26	37	(20)
Pleistocene Burried-Channel	345	(144)	315	(1.6)	16	133	(72)
Pleistocene	590	(466)	367	(3.4)	12	43	(23)
Pleistocene Undifferentiated	569	(445)	426	(2.2)	78	51	(29)
Cretacious	367	(388)	278	(2.0)	19	201	(84)
Pennsylvanian	614	(517)	476	(2.2)	5	185	(145)
Mississippian	397	(362)	285	(2.2)	41	197	(149)
Silurian	284	(198)	240	(1.8)	33	196	(96)
Devonian	443	(328)	350	(2.0)	49	168	(104)
Ordovician	360	(329)	256	(2.3)	27	337	(224)
Cambrian	347		---		1	400	
Unknown	387	(316)	289	(2.2)	45	Unknown	

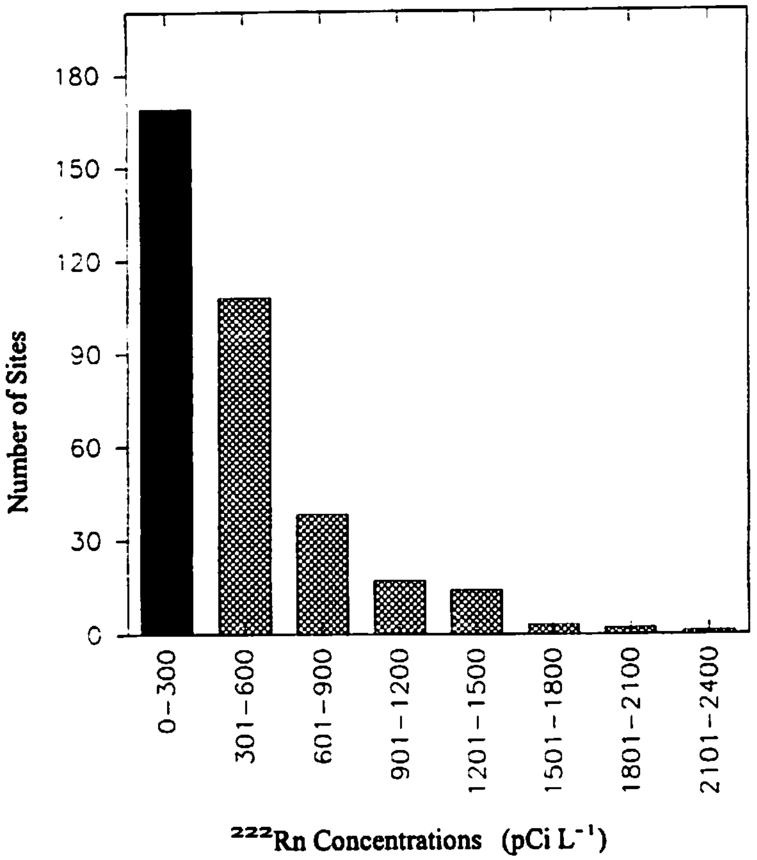

Fig. 1. Distribution of private-well water ^{222}Rn concentrations. Solid bar represents ^{222}Rn measurements less than 300 pCi L^{-1}.

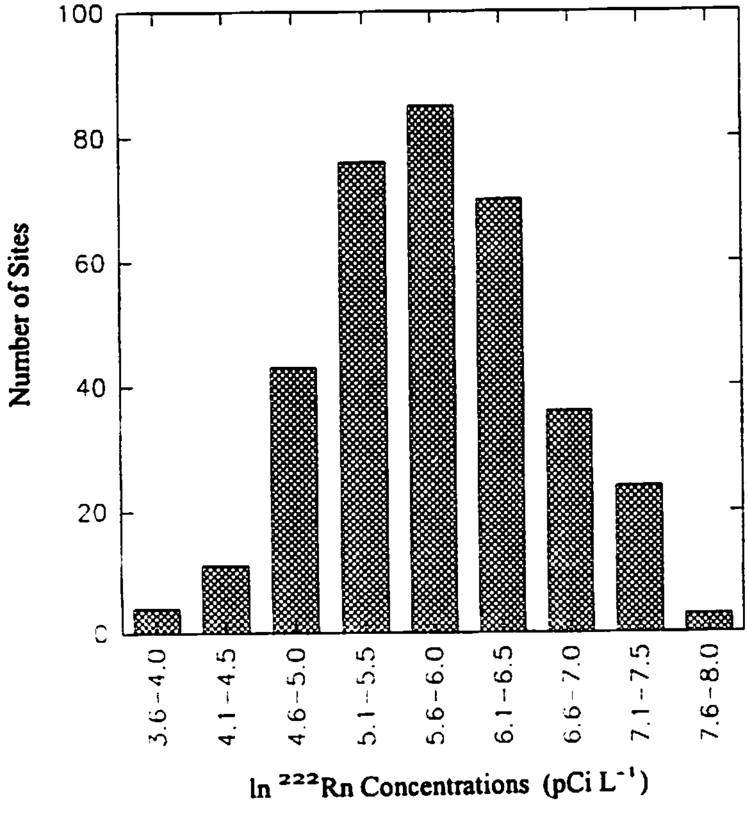

Fig. 2. Histogram showing log transformed distribution of private-well water ^{222}Rn concentrations.

RELATIVE RADON CONCENTRATIONS

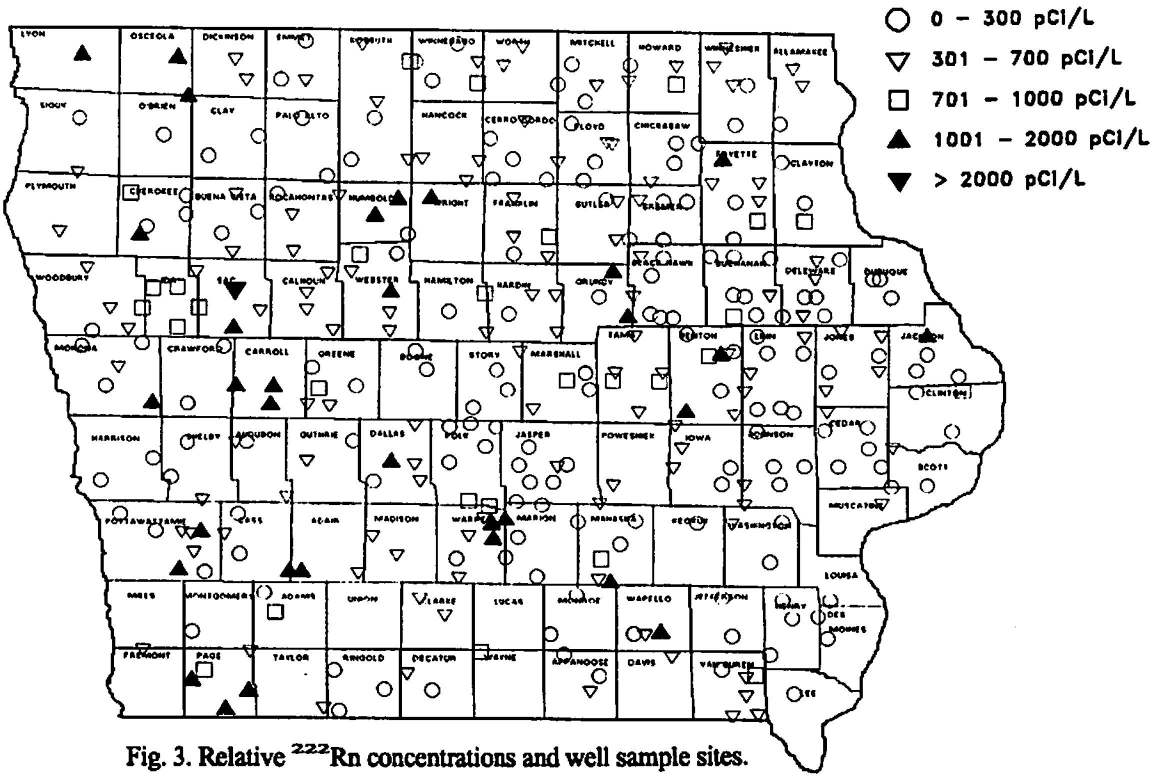

Fig. 3. Relative ^{222}Rn concentrations and well sample sites.

ALLUVIAL AQUIFER

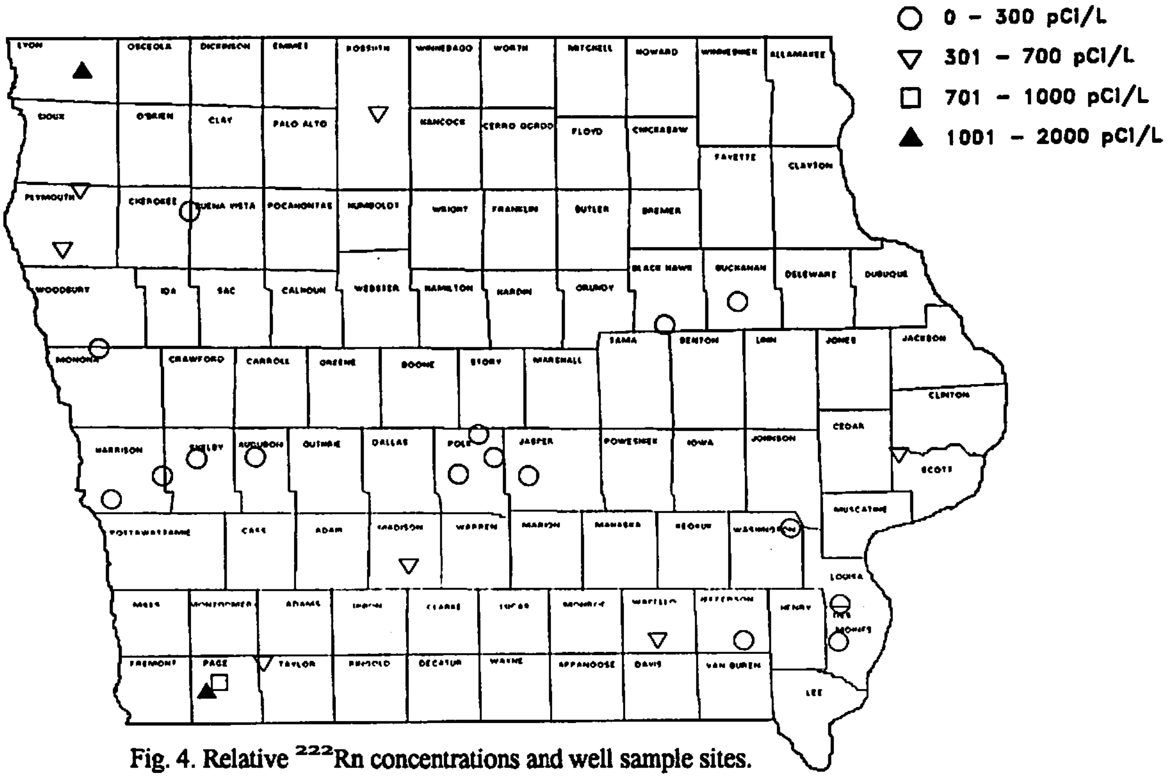

Fig. 4. Relative ^{222}Rn concentrations and well sample sites.

PLEISTOCENE AQUIFER

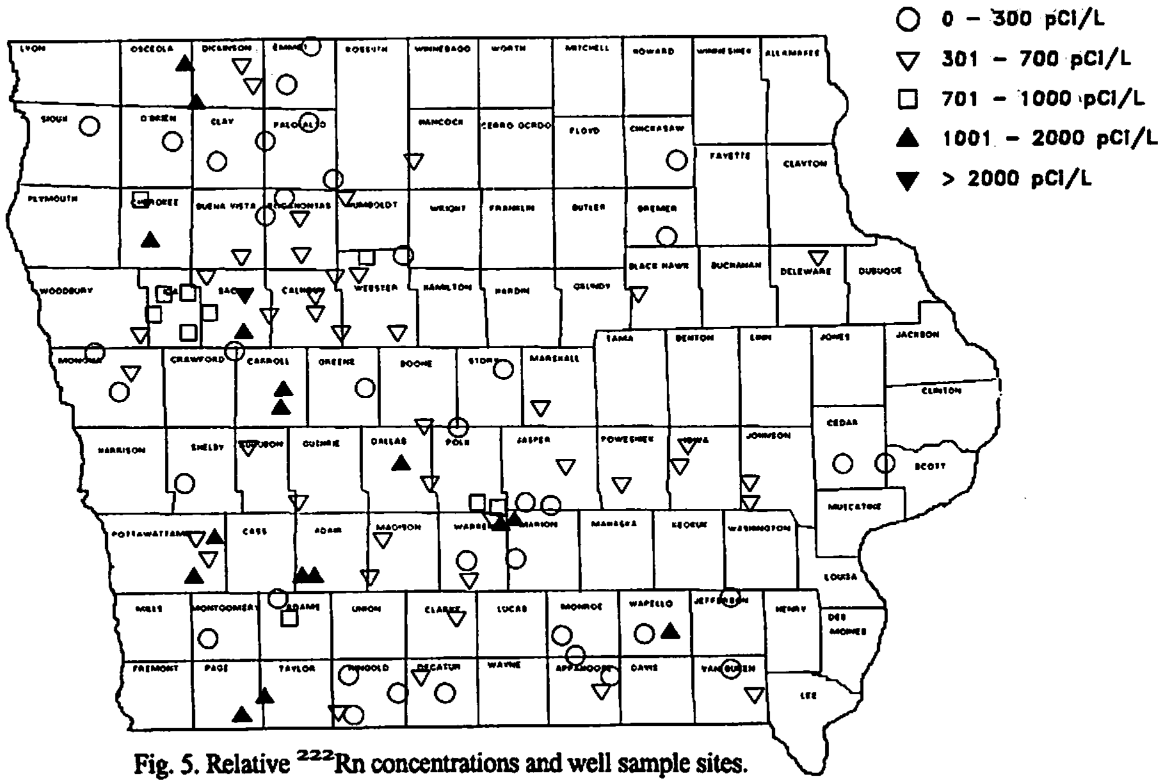

Fig. 5. Relative ^{222}Rn concentrations and well sample sites.

MISSISSIPPIAN AQUIFER

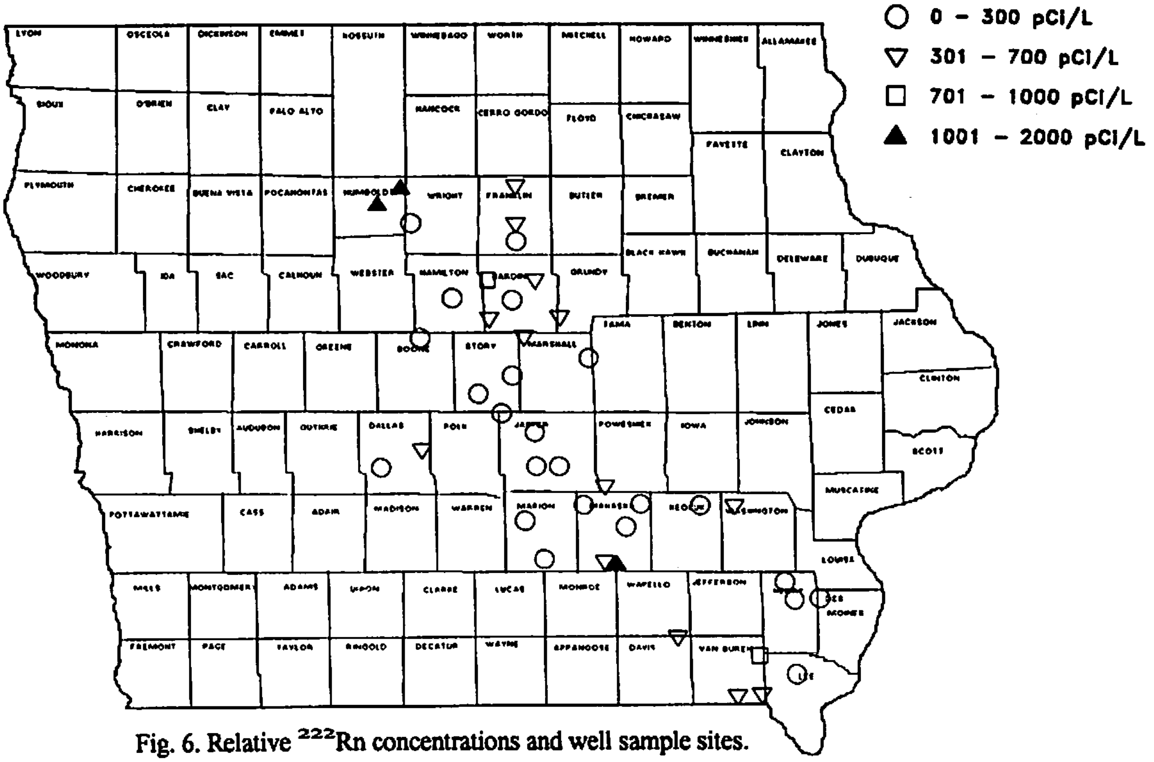

Fig. 6. Relative ^{222}Rn concentrations and well sample sites.

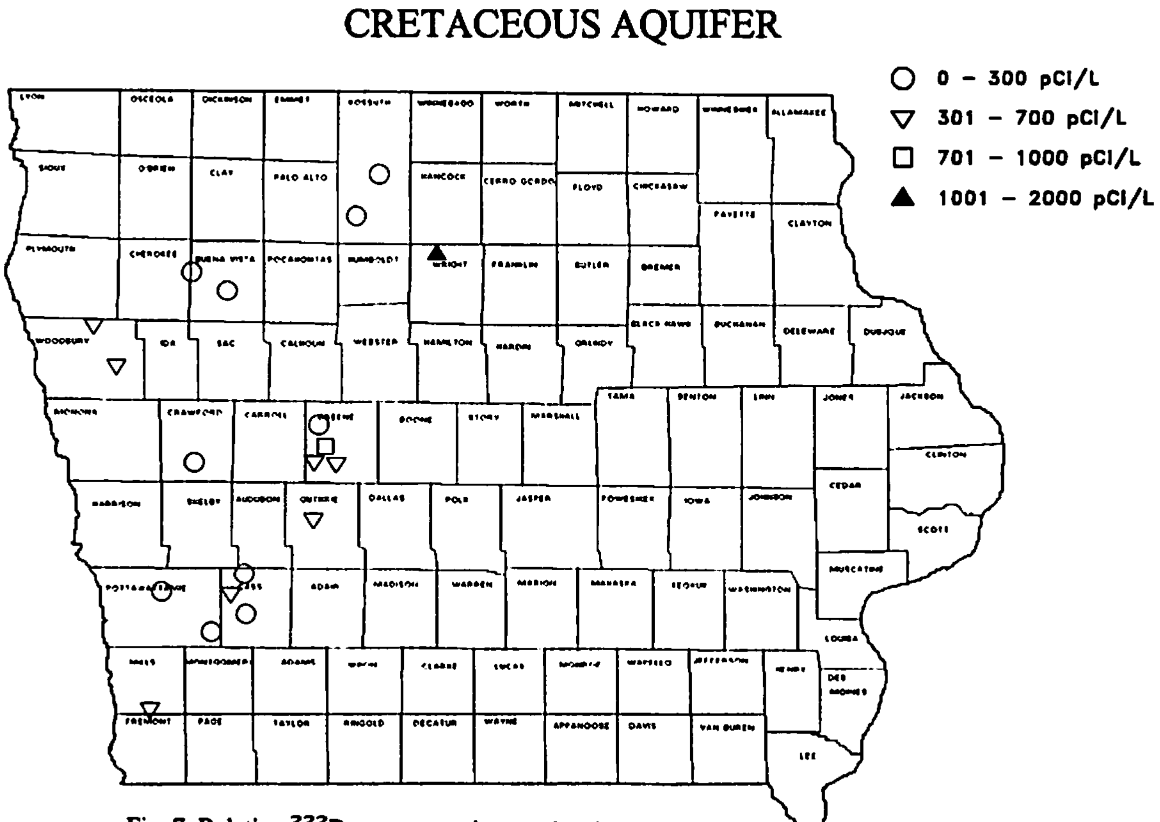

Fig. 7. Relative ^{222}Rn concentrations and well sample sites.

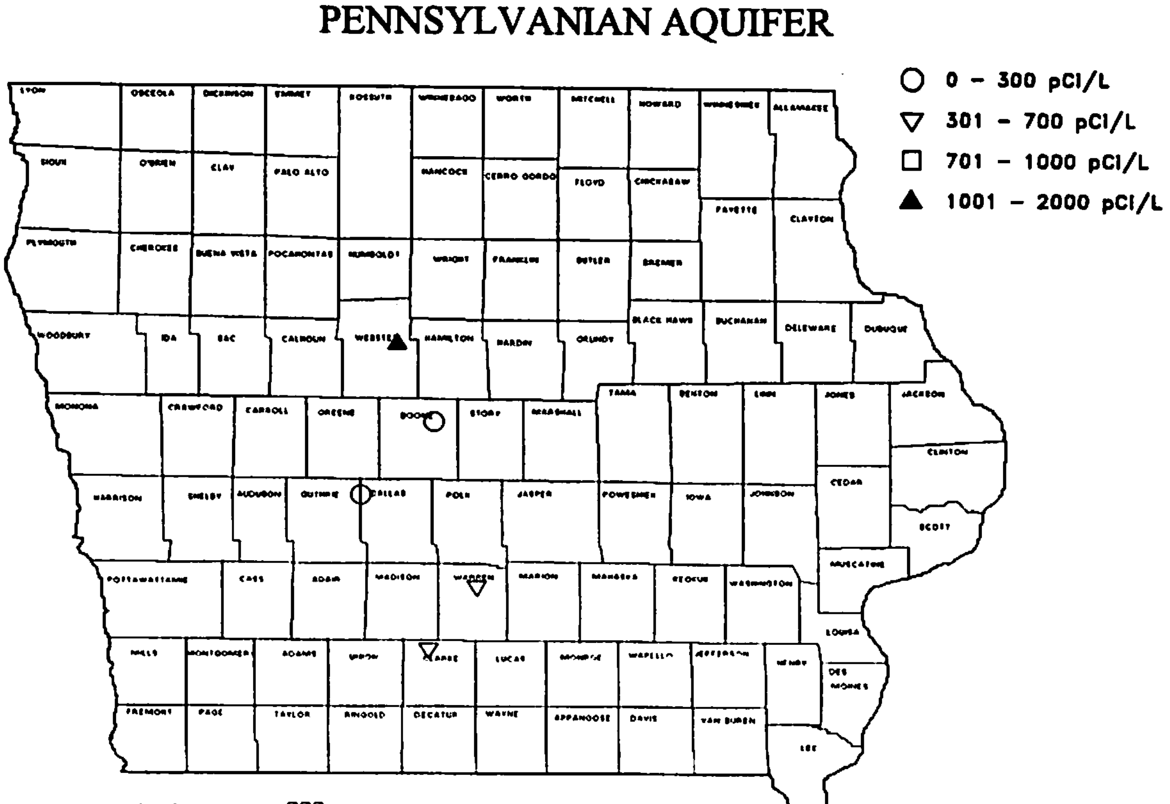

Fig. 8. Relative ^{222}Rn concentrations and well sample sites.

SILURIAN AQUIFER

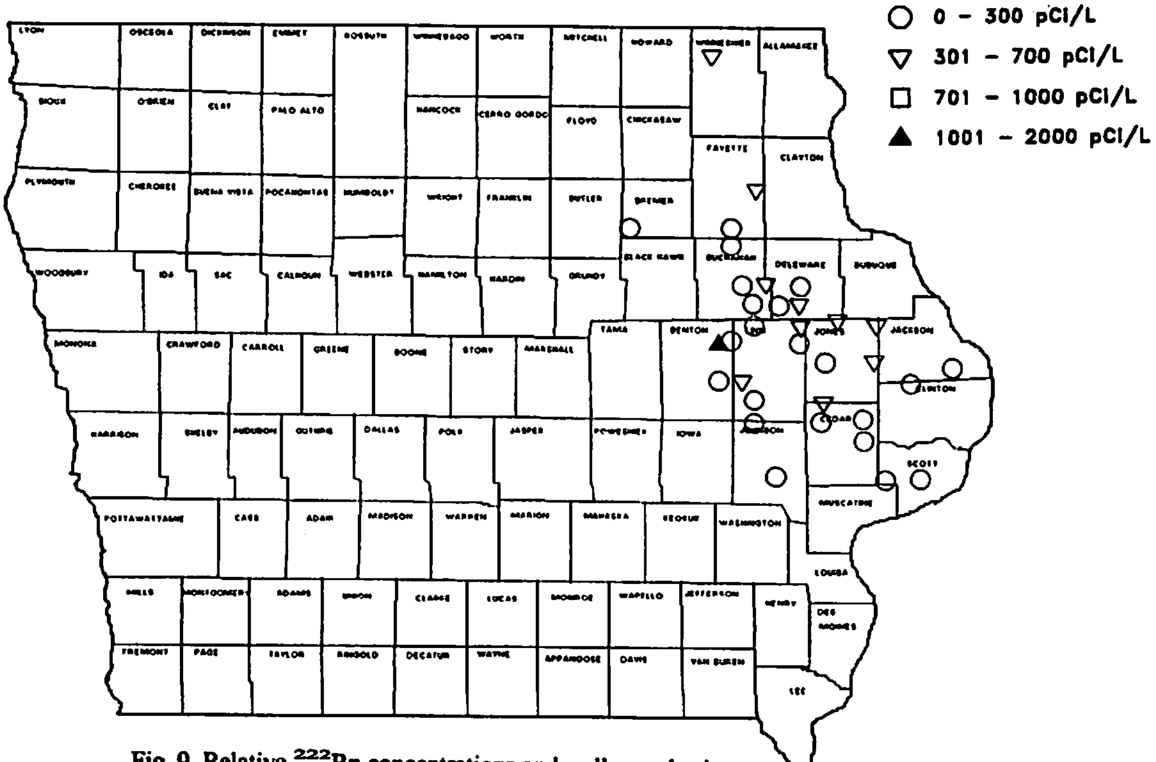

Fig. 9. Relative ^{222}Rn concentrations and well sample sites.

DEVONIAN AQUIFER

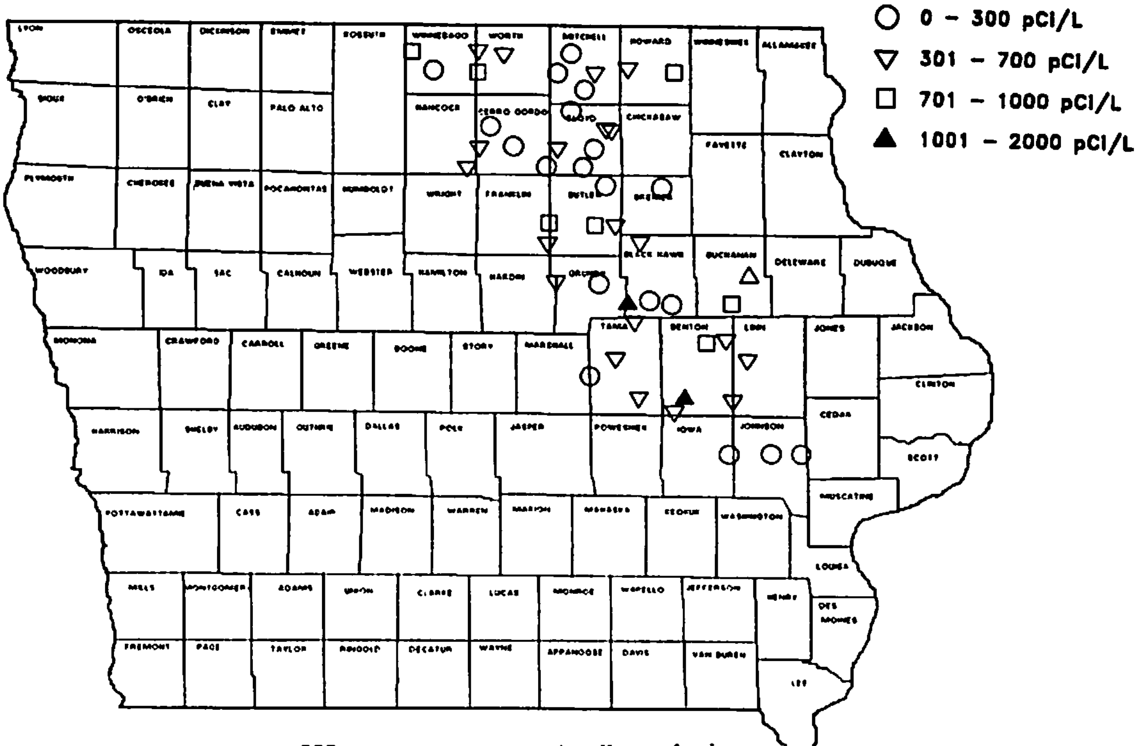

Fig. 10. Relative ^{222}Rn concentrations and well sample sites.

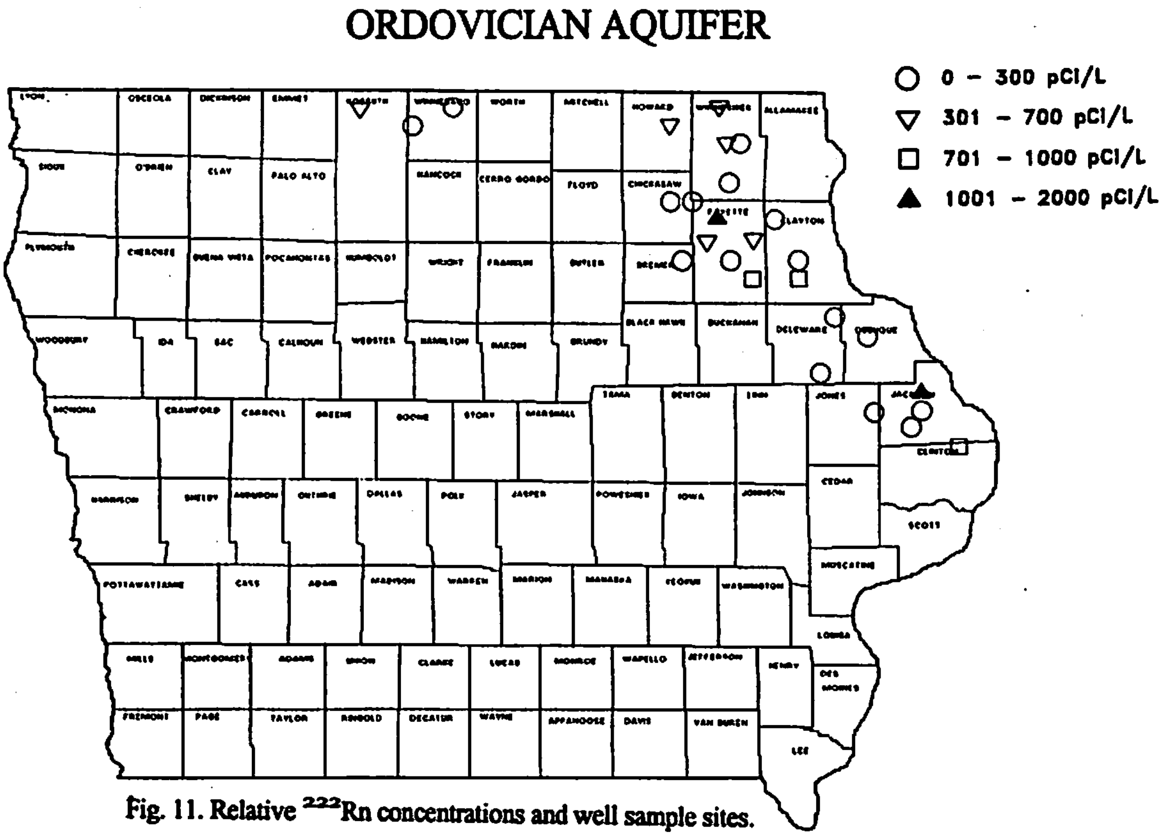

Fig. 11. Relative ^{222}Rn concentrations and well sample sites.

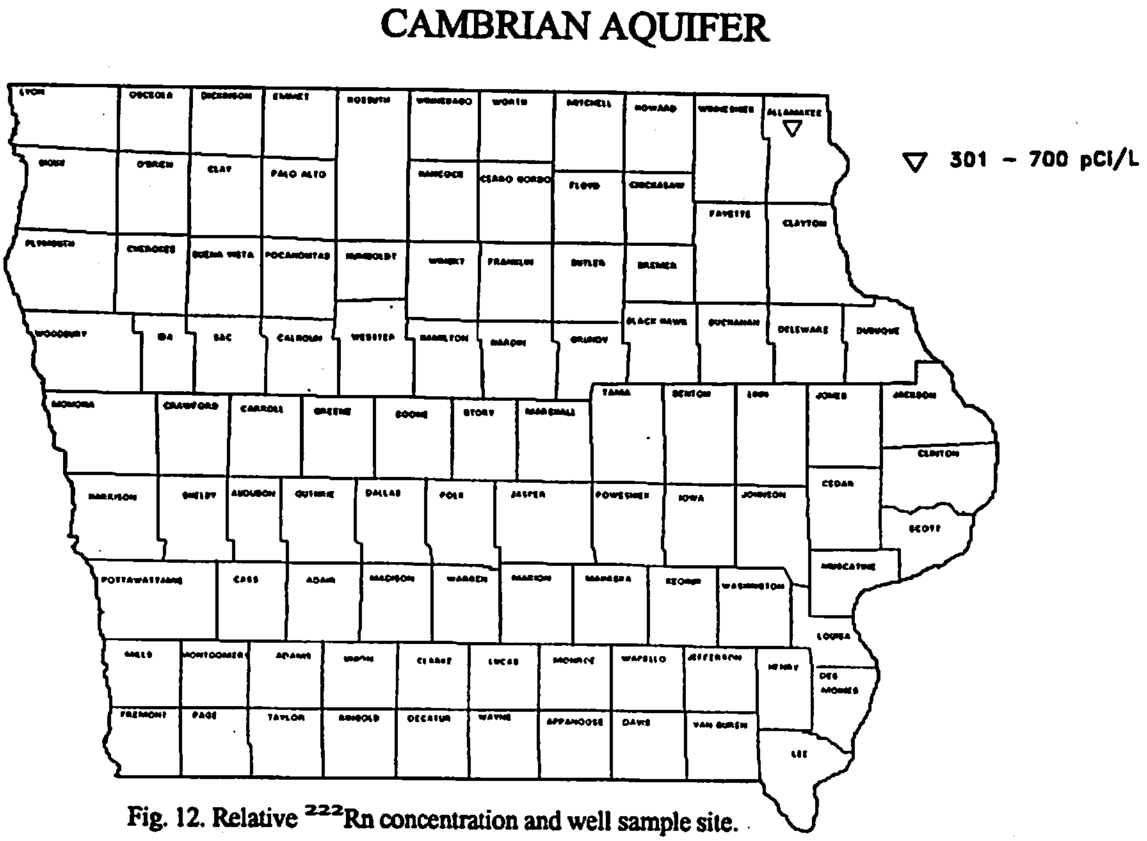

Fig. 12. Relative ^{222}Rn concentration and well sample site.