RADON-222 CONCENTRATIONS IN GROUND WATER AND SOIL GAS ON INDIAN RESERVATIONS IN WISCONSIN

By John F. DeWild and James T. Krohelski

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To Obtain
foot (ft)	0.3048	meter

Temperature, in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by use of the following equation:

$$°C = 5/9(°F-32).$$

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, the numerical value is the same as the concentration in parts per million.

Specific conductance is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

Radioactivity is expressed as picocuries per liter (pCi/L). A picocurie is the amount of radioactivity that yields 2.22 radioactive disintegrations per minute.

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Abstract

The weighted average radon-222 concentration of indoor air in homes located on Wisconsin Indian Reservations is 5.8 picocuries per liter, which exceeds the U.S. Environmental Protection Agency action limit of 4 picocuries per liter. Ground water is the principle source of drinking water on Wisconsin Indian Reservations and generally accounts for about 5 percent of the total indoor air radon-222 concentrations found in homes. To determine the distribution of radon-222, ground water from 29 private and community Wisconsin Indian Reservation wells and soil gas at a depth of about 3 feet below land surface adjacent to the wells were sampled. Sites with wells were distributed among the 11 Wisconsin Indian Reservations so that each Reservation contained at least 2 sites. The remaining seven sites were divided among the Reservation by acreage held by each tribe.

Ground-water samples were collected using a syringe technique after the wells had been purged sufficiently to reach chemical stability. Samples were then sent by overnight mail to the U.S. Geological Survey, National Water Quality Lab for analysis by liquid scintillation counting. Soil gas was collected in Lucas cells, using a small-diameter soil probe and peristaltic pump. The cells were then analyzed by Lucas cell alpha scintillation counting with a portable radon detector.

The highest radon-222 concentrations in ground water and soil gas are from sites with wells finished in the crystalline bedrock aquifer. Radon-222 concentrations in 29 ground-water samples collected from the sand and gravel and sedimentary and crystalline bedrock aquifers range from 260 to 22,000 picocuries per liter with a median concentration of 560 picocuries per liter. Only 2 of the 29 ground-water samples have radon-222 concentrations less than the U.S. Environmental Protection Agency proposed standard of 300 picocuries per liter. The highest radon-222 concentrations were found in ground water from wells in Shawano, Menominee, Forest, and Marathon counties. Radon-222 concentrations in soil gas range from 130 to 7,810 picocuries per liter with a median concentration of 560 picocuries per liter.

For sites with wells finished in the sand and gravel aquifer, the coefficient of determination (R^2) of the regression of concentration of radon-222 in ground water as a function of well depth is 0.003 and the significance level is 0.32, which indicates that there is not a statistically significant relation between radon-222 concentrations in ground water and well depth. The coefficient of determination of the regression of radon-222 in ground water and soil gas is 0.19 and the root mean square error of the regression line is 271 picocuries per liter. Even though the significance level (0.036) indicates a statistical relation, the root mean square error of the regression is so large that the regression equation would not give reliable predictions. Because of an inadequate number of samples, similar statistical analyses could not be performed for sites with wells finished in the crystalline and sedimentary bedrock aquifers.

INTRODUCTION

Radon-222 is a cancer-causing, naturally occurring radioactive gas resulting from the decay of uranium in rock, soil, and water that causes an estimated 14,000 deaths per year (U.S. Environmental Protection Agency, 1992a). Indoor air on

Wisconsin Indian Reservations has been sampled for radon-222 concentrations by the Indian Health Service (IHS), the Great Lakes Intertribal Council, and the individual tribes since 1988. From results of monitoring more than 1,000 Wisconsin Indian homes, U.S. Environmental Protection Agency (USEPA) in a comparative-risk-assessment project, determined the weighted average indoor air radon-222 concentration to be 5.8 pCi/L (picocuries per liter) (U.S. Environmental Protection Agency, 1992b). The USEPA action limit for radon-222 in indoor air is 4 pCi/L (U.S. Environmental Protection Agency, 1992a). The excess lifetime cancer risk associated with USEPA's action level of 4 pCi/L is 0.0017[1]. The estimated average excess lifetime cancer risk for the average concentration of 5.8 pCi/L found in Wisconsin Indian Reservation homes is 0.0025 for nonsmokers and 0.045 for smokers. (US. Environmental Protection Agency, 1992b).

The USEPA has determined that the threat from radon in drinking water is about half (48 percent) because of inhalation and about half (52 percent) because of ingestion (U.S. Environmental Protection Agency, 1994). Radon-222 found in ground water generally accounts for about 5 percent of the total indoor-air radon-222 concentrations found in homes where ground water is the principle source of drinking water (U.S. Environmental Protection Agency, 1992b). As an average, every 10,000 pCi/L of radon found in water contributes about 1 pCi/L of radon to the total indoor-air radon-222 concentration (U.S. Environmental Protection Agency, 1991a). Because ground water is the sole source of drinking water on Wisconsin Indian Reservations, it is possible that ground water is a major contributing factor to the elevated levels of radon-222 in indoor air.

The concentration of radon-222 in ground water in Wisconsin is generally unknown. However, analyses of ground water from eight private wells on the Menominee Indian Reservation in August of 1991 indicated that water from six of the eight wells sampled exceeded the USEPA proposed primary drinking-water standard of 300 pCi/L for radon-222 (U.S. Environmental Protection Agency, 1991b). Radon-222 concentrations in water from these wells ranged from 207 to 26,000 pCi/L (John DeWild, U.S. Geological Survey, written commun., 1991). These sites were selected from a group where radon-222 concentration of indoor air ranged from 0.8 to 77 pCi/L (Mark Mattson, Indian Health Services, written commun., 1991).

The objectives of the study reported here were to determine the range and areal distribution of radon-222 concentration in ground water and soil gas on Wisconsin Indian Reservations, and to determine if there is a relation between radon-222 concentrations in ground water to aquifer, well depth, and soil gas.

Purpose and Scope

This report presents results of a study conducted by the U.S. Geological Survey (USGS), in cooperation with the USEPA, that includes sampling private and community wells and soil gas on Wisconsin Indian Reservations for radon-222. Soil gas was sampled at a depth of about 3 ft adjacent to sampled wells.

The 29 sites where ground-water and soil-gas samples were collected are distributed among the Reservations so that each Reservation contained at least 2 sites. The remaining seven sites were divided among the Reservation by acreage held by each tribe (fig. 2). Specific sites were chosen according to the following criteria: (1) previous radon-222 concentrations for indoor air for a home supplied by a well had been obtained (preference was given to homes with an indoor air radon-222 concentration equal to or exceeding 4 pCi/L); (2) a driller's construction report was available; and (3) the site well was finished in the aquifer most used in the area.

Ground-water and soil-gas samples were collected from sites on the Winnebago, Menominee, Mole Lake, Lac Courte Orielles, Lac du Flambeau, Stockbridge-Munsee, Forest County Potawatomi,

[1]An excess cancer risk of 0.0017 means that an individual facing such a risk has an additional 1.7 chances in 1,000 of contracting cancer over a lifetime due to exposure to carcinogens from this source.

Oneida, Bad River, and Red Cliff Reservations. The locations of the Reservations and sampling sites are shown on figures 1 and 2, respectively.

Aquifer Descriptions and Site-Identification System

For the purposes of this report, aquifers from which water samples were analyzed for radon-222 are classified as either sand and gravel or bedrock. A detailed discussion of the bedrock aquifers is beyond the scope of this report. However, the hydrologic systems of the major river basins, including ground water, are described in a series of hydrologic atlases (Olcott, 1968; DeVaul and Green, 1971; Young and Hindall, 1972, 1973; Oakes and Hamilton, 1973; Hindall and Borman, 1974; Young and Skinner, 1974; Oakes and Cotter, 1975).

Aquifer Descriptions

The sand and gravel aquifer consists of unconsolidated deposits within the glacial drift that covers most of the State. The sand and gravel aquifer is not continuous but is present as outwash deposits, valley fills, and lenses within less permeable glacial deposits. Generally, the bedrock aquifer underlies the sand and gravel aquifer. The bedrock aquifer is laterally extensive and consists of sedimentary rock or crystalline metamorphic or igneous rock (fig. 1). In places, there is a good hydraulic connection between the sand and gravel and bedrock aquifers.

The bedrock aquifer underlying sites sampled on the Winnebago, Menominee, Mole Lake, Lac Courte Orielles, Lac du Flambeau, Stockbridge-Munsee, and Forest County Potawatomi Reservations is crystalline metamorphic or igneous rock. The bedrock aquifer underlying sites sampled on the Oneida, Bad River, and Red Cliff Reservations is sedimentary rock.

Site-Identification System

Each site sampled is identified by a local number based on the cadastral-survey system of the U.S. Government. The number consists of an abbreviation of the county name; the township, range and section; and a four digit number assigned to the well. For example, site OU-23/19E/18-0626 is in Outagamie County (OU), township 23 north, range 19 east, section 18; its sequence number is 626. On figure 2, only the county identifier and sequence number are used to identify each site.

METHODS

Methods used to collect and prepare ground-water and soil-gas samples and the methods of radon-222 analyses were determined after a literature review of available methods. The method used by the USGS for ground-water sampling and analysis was developed at the USGS National Water Quality Laboratory in 1988 after consultations with USEPA personnel at their Las Vegas, Nev., and Montgomery, Ala. labs (American Society for Testing and Materials, 1994). Methods used for collection and analysis of radon in soil gas were USEPA methods used by their field personnel to collect and analyze grab samples of indoor air for radon (U.S. Environmental Protection Agency, 1989). Brief descriptions of the methods used in this study follow.

Ground Water

Ground-water samples were collected using the syringe technique after the wells had been purged sufficiently to reach chemical stability (Cecil and Yang, 1988; Hardy and others, 1989). During purging, pH, temperature, specific conductance, and dissolved-oxygen concentrations were measured using a multiparameter probe equipped with a flow-through cell. The existing well pump was used to withdraw water from each well and samples were collected as close to the well head as possible to minimize the effects of pressure tanks and distribution lines on the radon-222 concentration. The ground-water samples were sent by overnight mail to the USGS, National Water Quality Lab (NWQL) for analysis by liquid scintillation counting.

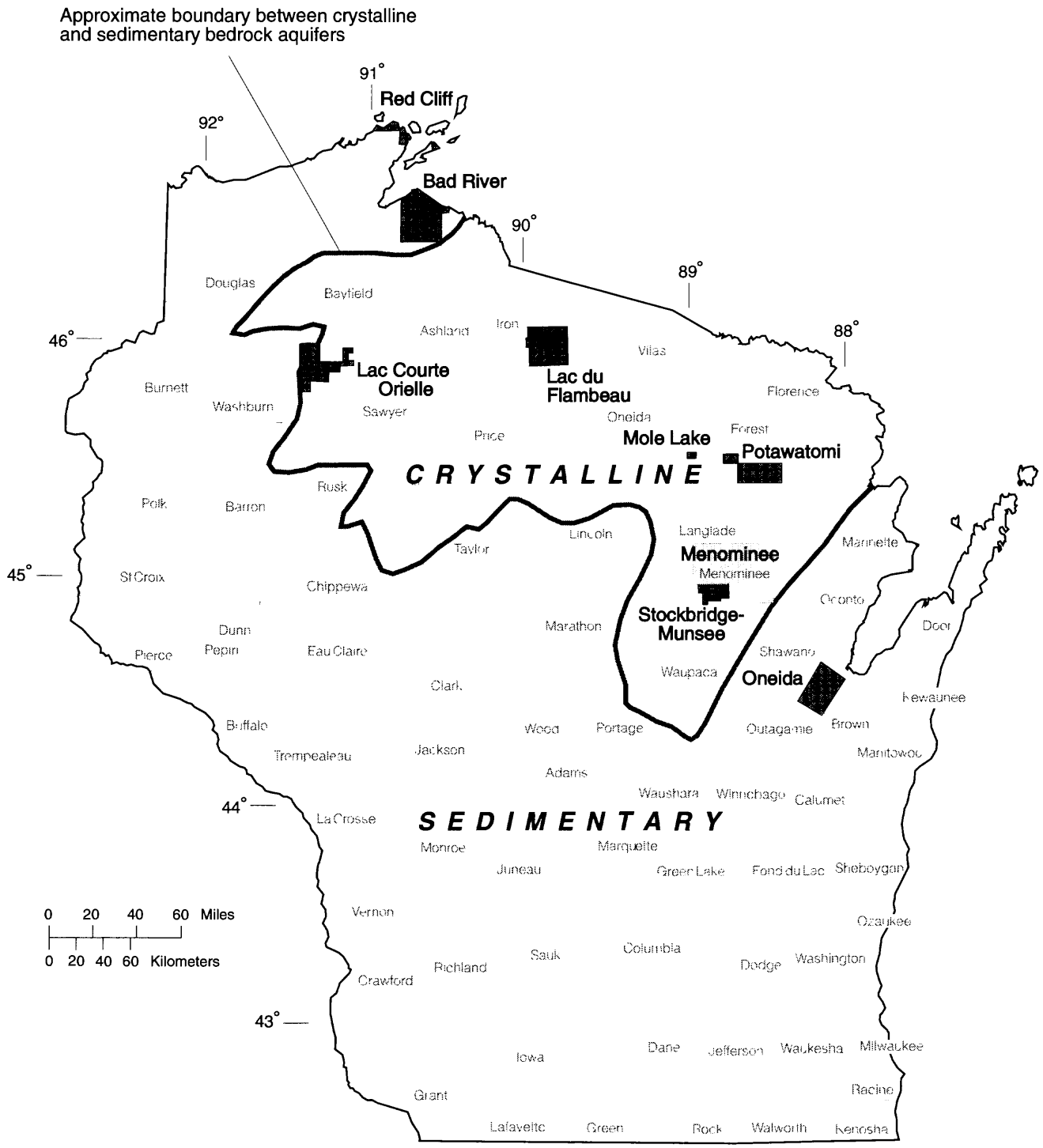

Figure 1. Location of Wisconsin Indian Reservations and the approximate boundary between crystalline and sedimentary bedrock aquifers (Winnebago and St. Croix Indian Reservations not shown).

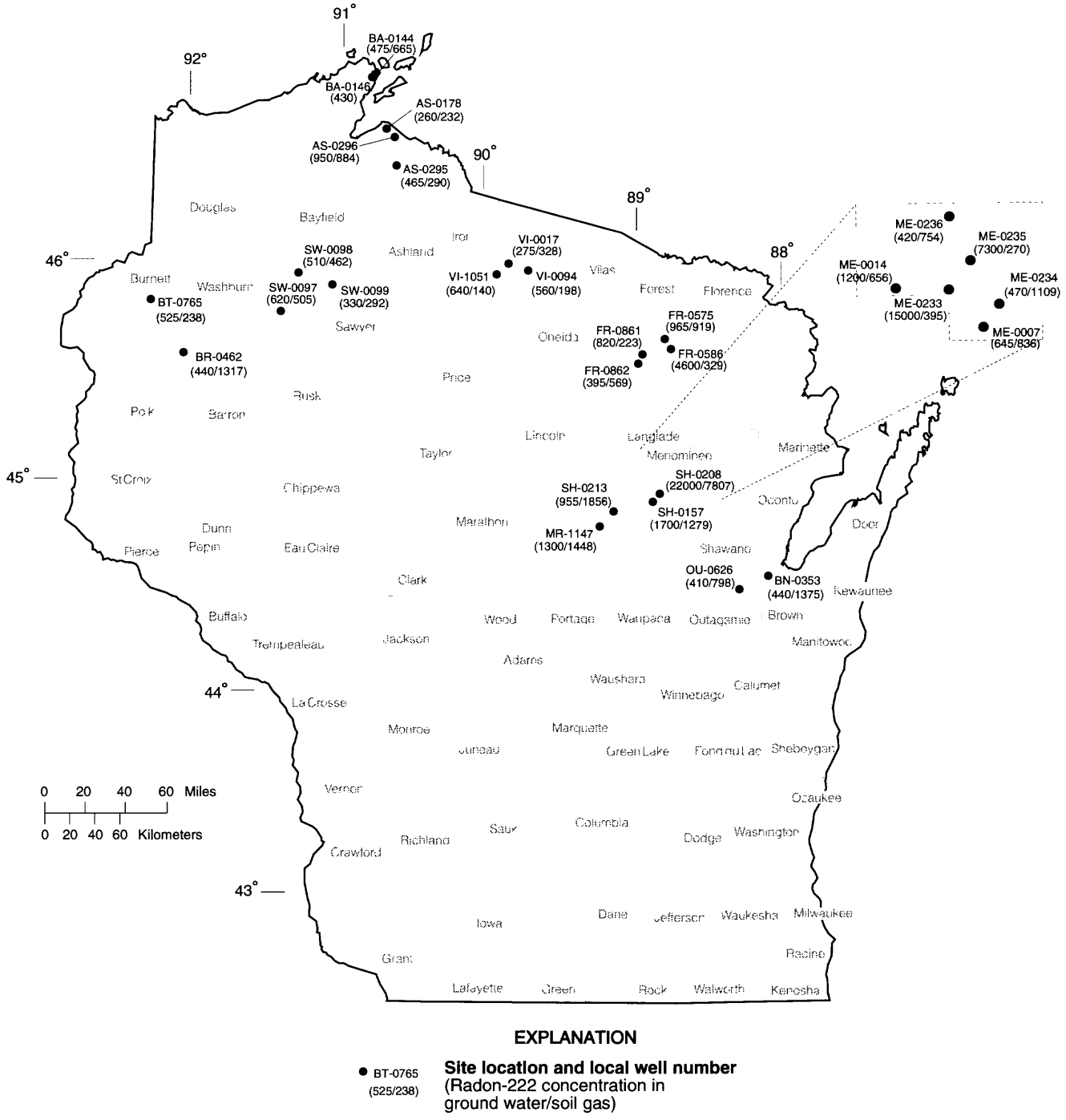

Figure 2. Location of sites sampled and radon-222 concentrations in ground water and soil gas.

Soil Gas

While the wells were being purged, soil gas adjacent to the wells was collected in Lucas cells at a depth of about 3 ft using a small diameter soil probe (Reimer, 1993). The soil gas was extracted from the probe into the sample cell through silicon-rubber tubing using a peristaltic pump. The tubing was equipped with an in-line filter to prevent soil from entering the sample cell. A constant pumping rate of 150 mL per minute was used throughout the soil gas collection. A sufficient volume was pumped to purge the cell 10 times to insure that the air inside the cell was soil-pore gas. The cells were then analyzed by Lucas cell alpha scintillation counting with a portable radon detector.

Quality Control

One duplicate sample of ground water and one duplicate of soil gas was collected during each sampling day. Each duplicate sample was collected immediately after and treated identically to the corresponding environmental sample.

The Radchem section at the NWQL calibrates the liquid scintillation counters daily. In addition, at least two standards and a blank are counted prior to each run and a blank or standard is counted after every 10 samples. Individual efficiencies are calculated for each batch of samples.

RADON-222 CONCENTRATIONS

The analyses of radon-222 from 29 sites on 11 Wisconsin Indian Reservations defines the range and areal distribution of radon-222 concentrations in ground water and soil gas. These radon-222 concentrations in ground water are compared to aquifer, well depth, and soil-gas radon-222 concentrations. Table 1 lists ground-water levels, construction data and aquifers tapped by the 29 wells sampled. Table 2 lists the field parameters and radon-222 analyses of ground water and soil gas for the 29 sites sampled. For selected sites, duplicate analyses are listed but only the first analysis listed for each site in table 2 is used for interpretation.

Ground Water

Radon-222 concentrations in the 29 groundwater samples collected from the sand and gravel and sedimentary and crystalline bedrock aquifers range from 260 to 22,000 pCi/L with a median concentration of 560 pCi/L. Only two (VI-40/05E/08-0017 and AS-48/03W/26-0178) of the 29 groundwater samples had radon-222 concentrations below the USEPA proposed standard of 300 pCi/L. Radon-222 concentrations in ground water from wells located in Shawano, Menominee, Forest, and Marathon counties show particularly high concentrations (fig. 2). With the exception of ground water from one well in Ashland County, the 11 highest radon-222 concentrations were found in ground water from wells in these counties.

The highest radon-222 concentrations in ground water are from wells finished in the crystalline bedrock aquifer. Four wells finished in the crystalline bedrock aquifer have radon-222 concentrations ranging from 1,700 to 22,000 pCi/L with a median concentration of 11,100 pCi/L. Depths of the wells finished in the crystalline bedrock aquifer range from 40 to 328 ft. Ground water from five wells finished in sedimentary bedrock aquifers have radon-222 concentrations ranging from 430 to 950 pCi/L with a median concentration of 450 pCi/L. Wells finished in the sedimentary bedrock aquifer are generally deeper than the other aquifers and range from 103 to 935 ft deep. Concentrations of radon-222 in ground water from 20 wells finished in the sand and gravel aquifer range from 260 to 4,600 pCi/L with a median value of 540. The total depths of the sand and gravel wells range from 38 to 243 ft.

The sufficient number of sample analyses from the sand and gravel aquifer allows a comparison of radon-222 concentrations in ground water with well depth. All analyses for radon-222 in ground water from the sand and gravel aquifer are used except for site FR-36/13E/35-0586 (fig. 2) which has an anomalously high concentration and well depth. The coefficient of determination of the regression line of the concentration of radon-222 in ground water compared to depth of well is 0.003 and the significance level is 0.32, indicating that

Table 1. Water-level and well-construction data for wells sampled on Wisconsin Indian Reservations
[Data is from well-construction reports; --, no data available; SED, sedimentary bedrock aquifer; SDGV, sand and gravel aquifer; CRYS, crystaline bedrock aquifer]

Local well number	Reservation name and county	Water-level measurement date	Land-surface altitude (feet above sea level)	Water-level altitude (feet above sea level)	Depth of well (feet)	Casing depth (feet)	Opening length (feet)	Primary aquifer
AS-47/02W/25-0295	Bad River, Ashland	06-85	1,090	718	985	971	34	SED
AS-48/02W/31-0296	Bad River, Ashland	08-28-73	625	610	252	243	9	SED
AS-48/03W/26-0178	Bad River, Ashland	07-15-70	610	607	137	134	3	SDGV
BA-51/03W/31-0144	Red Cliff, Bayfield	07-19-67	665	605	200	78	122	SED
BA-51/03W/31-0146	Red Cliff, Bayfield	05-25-71	670	620	200	73	127	SED
BN-24/19E/27-0353	Oneida, Brown	01-25-83	690	665	103	45	58	SED
BR-36/14W/28-0462	St. Croix, Barron	11-08-67	1,290	1,235	94	83	11	SDGV
BT-38/15W/02-0765	St. Croix, Burnett	10-28-80	1,060	1,000	87	81	6	SDGV
FR-35/12E/23-0861	Mole Lake, Forest	08-30-71	1,535	1,524	59	49	10	SDGV
FR-35/12E/28-0862	Mole Lake, Forest	12-07-92	1,600	1,552	84	81	3	SDGV
FR-36/13E/26-0575	Potawatomi, Forest	06-08-82	1,715	1,615	118	118	--	SDGV
FR-36/13E/35-0586	Potawatomi, Forest	07-01-78	1,800	1,640	243	237	6	SDGV
ME-28/15E/21-0233	Menominee, Menominee	10-14-92	870	864	138	28	110	CRYS
ME-28/15E/26-0007	Menominee, Menominee	09-61	840	--	82	72	10	SDGV
ME-28/16E/30-0234	Menominee, Menominee	01-03-76	860	830	50	47	3	SDGV
ME-29/14E/20-0014	Menominee, Menominee	12-03-74	1,060	1,052	53	41	12	SDGV
ME-29/15E/25-0235	Menominee, Menominee	10-14-92	860	849	203	20	183	CRYS
ME-30/16E/35-0236	Menominee, Menominee	09-20-93	880	870	83	80	3	SDGV
MR-27/10E/24-1147	Winnebago, Monroe	07-16-77	1,220	1,185	84	77	7.5	SDGV
OU-23/19E/18-0626	Oneida, Outagamie	--	740	--	123	47	76	SED
SH-28/11E/34-0213	Winnebago, Shawano	07-10-72	1,200	1,180	59	56	3	SDGV
SH-28/13E/16-0157	Stockbridge-Munsee, Shawano	--	1,110	--	40	40	--	CRYS
SH-28/13E/16-0208	Stockbridge-Munsee, Shawano	03-20-90	1,100	1,077	328	46	282	CRYS
SW-39/07W/01-0099	Lac Courte Orielles, Sawyer	06-16-70	1,335	1,309	81	61	20	SDGV
SW-39/08W/08-0097	Lac Courte Orielles, Sawyer	07-18-70	1,300	1,290	44	36	8	SDGV
SW-40/08W/02-0098	Lac Courte Orielles, Sawyer	09-21-79	1,350	1,330	171	165	6	SDGV
VI-40/04E/13-1051	Lac du Flambeau, Vilas	05-25-87	1,600	1,587	38	33	5	SDGV
VI-40/05E/08-0017	Lac du Flambeau, Vilas	11-02-62	1,590	1,570	61	49	12	SDGV
VI-40/05E/09-0094	Lac du Flambeau, Vilas	03-15-78	1,600	1,584	90	84	6	SDGV

Table 2. Temperature, specific conductance, dissolved-oxygen concentrations, pH, and radon-222 concentrations in ground water and soil gas at about a 3 foot depth onWisconsin Indian Reservations, 1994
[DEG C, degress Celsius; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; pCi/L, picocuries per liter]

Local identifier	Date	Temperature water (DEG C)	Specific conductance (µS/cm)	Oxygen dissolved (mg/L)	pH water whole field (standard units)	Radon-222 water total (pCi/L)	Radon-222 soil gas total (pCi/L)
AS-47/02W/25-0295	10-12-93	8.0	210	0	8.5	450	290
AS-47/02W/25-0295	10-12-93	--	--	--	--	480	--
AS-48/02W/31-0296	10-12-93	8.0	408	0	7.8	950	884
AS-48/03W/26-0178	10-12-93	9.5	265	0.8	8.1	260	260
AS-48/03W/26-0178	10-12-93	--	--	--	--	--	200
BA-51/03W/31-0144	10-13-93	8.0	198	7.9	7.3	470	660
BA-51/03W/31-0144	10-13-93	--	--	--	--	480	670
BA-51/03W/31-0146	10-13-93	8.0	195	8.1	7.3	430	--
BN-24/19E/27-0353	09-08-93	13.5	305	1.3	7.7	440	1,480
BN-24/19E/27-0353	09-08-93	--	--	--	--	--	1,270
BR-36/14W/28-0462	09-23-93	9.5	239	7.3	7.0	440	1,240
BR-36/14W/28-0462	09-23-93	--	--	--	--	--	1,390
BT-38/15W/02-0765	09-23-93	12.0	168	9.9	8.4	520	240
BT-38/15W/02-0765	09-23-93	--	--	--	--	530	--
FR-35/12E/23-0861	09-15-93	8.0	299	5.9	7.8	820	210
FR-35/12E/23-0861	09-15-93	--	--	--	--	--	230
FR-35/12E/28-0862	09-15-93	9.5	239	10.4	7.7	400	570
FR-35/12E/28-0862	09-15-93	--	--	--	--	490	--
FR-36/13E/26-0575	09-16-93	9.5	522	9.7	7.4	970	920
FR-36/13E/26-0575	09-16-93	--	--	--	--	960	--
FR-36/13E/35-0586	09-16-93	10.5	303	9.4	7.6	4,600	330
FR-36/13E/35-0586	09-16-93	--	--	--	--	--	330
ME-28/15E/21-0233	10-07-93	10.0	408	.5	7.9	15,000	380
ME-28/15E/21-0233	10-07-93	--	--	--	--	15,000	410
ME-28/15E/26-0007	09-09-93	10.0	472	0	7.2	640	840

Table 2. Temperature, specific conductance, dissolved-oxygen concentrations, pH, and radon-222 concentrations in ground water and soil gas at about a 3 foot depth on Wisconsin Indian Reservations, 1994--Continued

Local identifier	Date	Temperature water (DEG C)	Specific conductance (µS/cm)	Oxygen dissolved (mg/L)	pH water whole field (standard units)	Radon-222 water total (pCi/L)	Radon-222 soil gas total (pCi/L)
ME-28/15E/26-0007	09-09-93	--	--	--	--	650	--
ME-28/16E/30-0234	10-06-93	9.0	411	10.4	7.6	470	1,110
ME-29/14E/20-0014	09-09-93	10.0	490	3.3	6.9	1,200	660
ME-29/15E/25-0235	10-06-93	10.0	274	.8	8.0	7,200	270
ME-29/15E/25-0235	10-06-93	--	--	--	--	7,400	--
ME-30/16E/35-0236	10-06-93	10.0	356	0	7.7	420	740
ME-30/16E/35-0236	10-06-93	--	--	--	--	--	770
MR-27/10E/24-1147	09-21-93	12.0	405	3.0	7.6	1,300	1,470
MR-27/10E/24-1147	09-21-93	--	--	--	--	--	1,470
OU-23/19E/18-0626	09-08-93	11.0	490	0	7.2	430	800
OU-23/19E/18-0626	09-08-93	--	--	--	--	390	--
SH-28/11E/34-0213	09-21-93	14.5	626	7.4	7.6	990	1,860
SH-28/11E/34-0213	09-21-93	--	--	--	--	920	--
SH-28/13E/16-0157	09-01-93	15.0	297	1.1	7.6	1,700	1,250
SH-28/13E/16-0157	09-01-93	--	--	--	--	1,700	1,310
SH-28/13E/16-0208	09-07-93	8.0	296	.4	7.5	22,000	7,810
SW-39/07W/01-0099	10-14-93	8.5	76	7.0	5.6	330	290
SW-39/08W/08-0097	10-14-93	8.5	318	4.8	7.0	620	560
SW-39/08W/08-0097	10-14-93	--	--	--	--	--	450
SW-40/08W/02-0098	10-14-93	8.5	160	0	7.8	520	460
SW-40/08W/02-0098	10-14-93	--	--	--	--	500	--
VI-40/04E/13-1051	09-30-93	7.5	87	9.4	6.7	640	130
VI-40/04E/13-1051	09-30-93	--	--	--	--	--	140
VI-40/05E/08-0017	09-30-93	7.5	210	4.9	6.5	270	330
VI-40/05E/08-0017	09-30-93	--	--	--	--	280	--
VI-40/05E/09-0094	09-30-93	8.5	175	0	8.0	560	200

there is not a statistically significant relation between radon-222 concentrations in ground water and well depth.

Soil Gas

Concentrations of radon-222 in soil gas range from 130 to 7,810 pCi/L with a median concentration of 560 pCi/L. Because sites BA-51/03W/31-0144 and BA-51/03W/31-0146 were within 50 ft of one another and the well constructions were similar, soil gas was sampled only at BA-51/03W/31-0144. No area of high radon-222 concentration in soil gas is apparent.

The highest concentration of radon-222 in soil gas, 7,810 pCi/L, is adjacent to a well (SH-28/13E/16-0208) finished in the crystalline bedrock aquifer. Soil-gas radon-222 concentrations at sites adjacent to wells finished in the crystalline bedrock aquifer range from 380 to 7,810 pCi/L and have a median value of 815 pCi/L. Concentrations of radon-222 in soil gas range from 290 to 1,480 with a median of 200 pCi/L adjacent to sedimentary bedrock wells, and range from 130 to 1,860 with a median of 560 pCi/L adjacent to sand and gravel wells.

With the exception of one site (FR-36/13E/35-0586), the ranges of concentrations of radon-222 in both ground water and soil gas at the sand and gravel sites are similar—260 to 1,300 pCi/L and 200 to 1,860 pCi/L, respectively. For the sites with wells finished in the sand and gravel aquifer (excluding FR-36/13E/35-0586), concentration of radon-222 in soil gas is correlated to radon-222 concentration in ground water (fig. 3). The coefficient of determination of the regression of radon-222 in ground water to soil gas is 0.19 and the root mean square error of the regression line is 271 pCi/L. Even though the significance level (0.036) indicates a statistical relation, the root mean square error of the regression is large enough so that the regression equation would not give reliable predictions.

SUMMARY

Samples of ground water and soil gas were collected for analysis of radon-222 concentrations at a minimum of 2 sites on each of the 11 Wisconsin Indian Reservations. Radon-222 concentrations in ground-water analyses range from 260 to 22,000 pCi/L. Only 2 of the 29 sites sampled have a radon-222 concentration in ground water less than the USEPA proposed drinking water standard of 300 pCi/L. The area encompassing Shawano, Menominee, Forest, and Marathon counties has a large number of sites with high concentrations of radon-222 in ground water. Radon-222 concentrations in ground water and soil gas are generally higher at sites where wells are finished in the crystalline bedrock aquifer than sites where wells are finished in the sedimentary bedrock or sand and gravel aquifers.

For the sites where wells are finished in the sand and gravel aquifer, there is no correlation between radon-222 concentration in ground water to well depth, and, even though there is a statistically significant correlation of radon-222 in ground water to soil gas, the regression equation would not give reliable predictions.

Concentrations of radon-222 in soil gas analyses range from 130 to 7,810 pCi/L with a median concentration of 560 pCi/L. With the exception of one site (FR-36/13E/35-0586), the ranges of concentrations of radon-222 in ground water and soil gas for the sand and gravel sites are similar, 260 to 1,300 pCi/L and 200 to 1,860 pCi/L, respectively.

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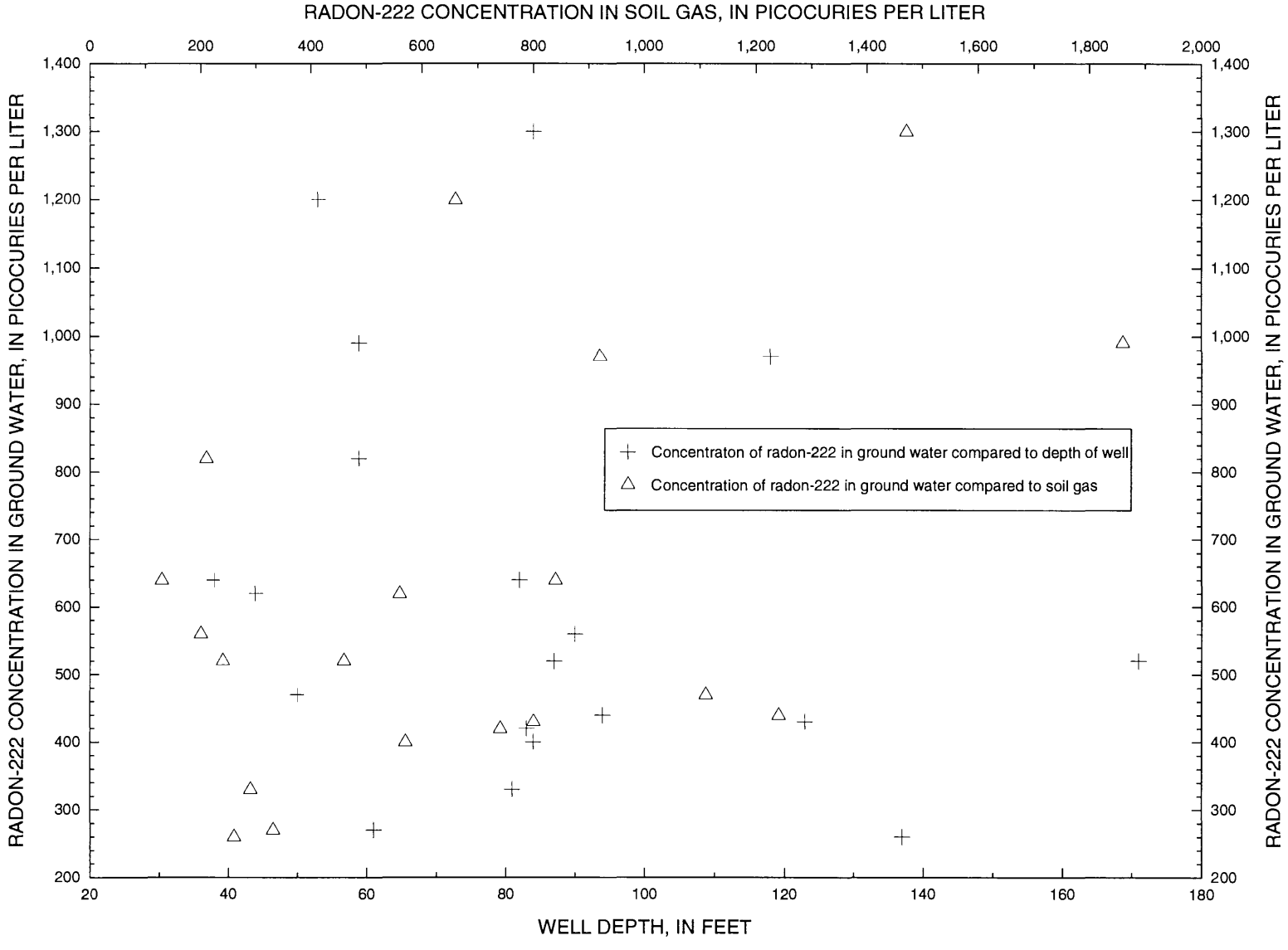

Figure 3. Radon-222 concentration in ground water from the sand and gravel aquifer compared to well depth and radon-222 concentration in ground water compared to soil gas at about a 3 foot depth near the well on Wisconsin Indian Reservations.

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