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Soil gas radon analysis in some areas of Northern Punjab, India

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Abstract The radon concentration levels in soil samples from 39 locations of Northern Punjab are measured using AlphaGUARD (PQ 2000 PRO Model) of Genitron instruments, Germany. The radon concentration in soil varies from 0.3 to 35.8 kBq/l. The minimum value of radon is observed in Talwandi Choudhrian and is maximum for Nushera Dhala. The soil gas radon is correlated with soil temperature, pressure, and humidity to observe the effect of these parameters on radon release. The soil gas radon values in the study area are compared with that obtained in groundwater. The results are also compared with the available radon data for other parts of Punjab and Himachal Pradesh.

Keywords Radon in soil · AlphaGUARD · Northern Punjab · Health risk assessment

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Introduction

Monitoring of any release of radioactive material to the environment is necessary for environmental protection. The world is naturally radioactive, and around 90% of human radiation exposure arises from natural sources such as cosmic radiation, exposure to radon gas, and terrestrial radiation. Terrestrial radiation is due to radioactive nuclides present in varying amounts in soil, building materials, water, rocks, and atmosphere. The measurement of the ^{222}Rn concentration in soil gas, in principle, can be used as a method of evaluating the potential for elevated indoor ^{222}Rn concentrations (Iskandar et al. 2005). Next to air and water, soil is generally considered as the third main environmental component. In practice, soil provides basis, also in literal sense, of a substantial part of the collective life on the earth via the capture of sun energy by green plants. Soil pollution could be typified as a malfunctioning of soil as an environmental component following its contamination particularly as a result of human activities. The determination of pollutants in soil is of great importance owing to the fact that plant roots are one of the ways of incorporating them into the food chain (Gomenz et al. 1997). Radon (Rn^{222}) is a descendant nuclide of radium (Ra^{226}), which in turn comes from the long-lived antecedent, uranium (U^{238}). The short half-life of Rn^{222} (3.82 days) limits its diffusion in soil, so the radon measured at the ground surface cannot be released from a deep origin, unless there exists a driving mechanism other than mere diffusion.

^{222}Rn and ^{220}Rn originate in the earth form ^{238}U and ^{232}Th series. The diffusion length for ^{222}Rn, i.e., the average distance an atom can move through dry soil before decaying, is about 1.6 m, while it is only 2 cm for Thoron because of relatively shorter half-life, i.e., 55.6 s (Muller Associates Inc. 1988). This is what makes ^{222}Rn a greater health hazard.

In the present investigations, the survey has been carried out for the first time in some areas of Northern Punjab for the measurement of radon concentration in soil for the purpose of uranium prospection and radon health risk assessment.

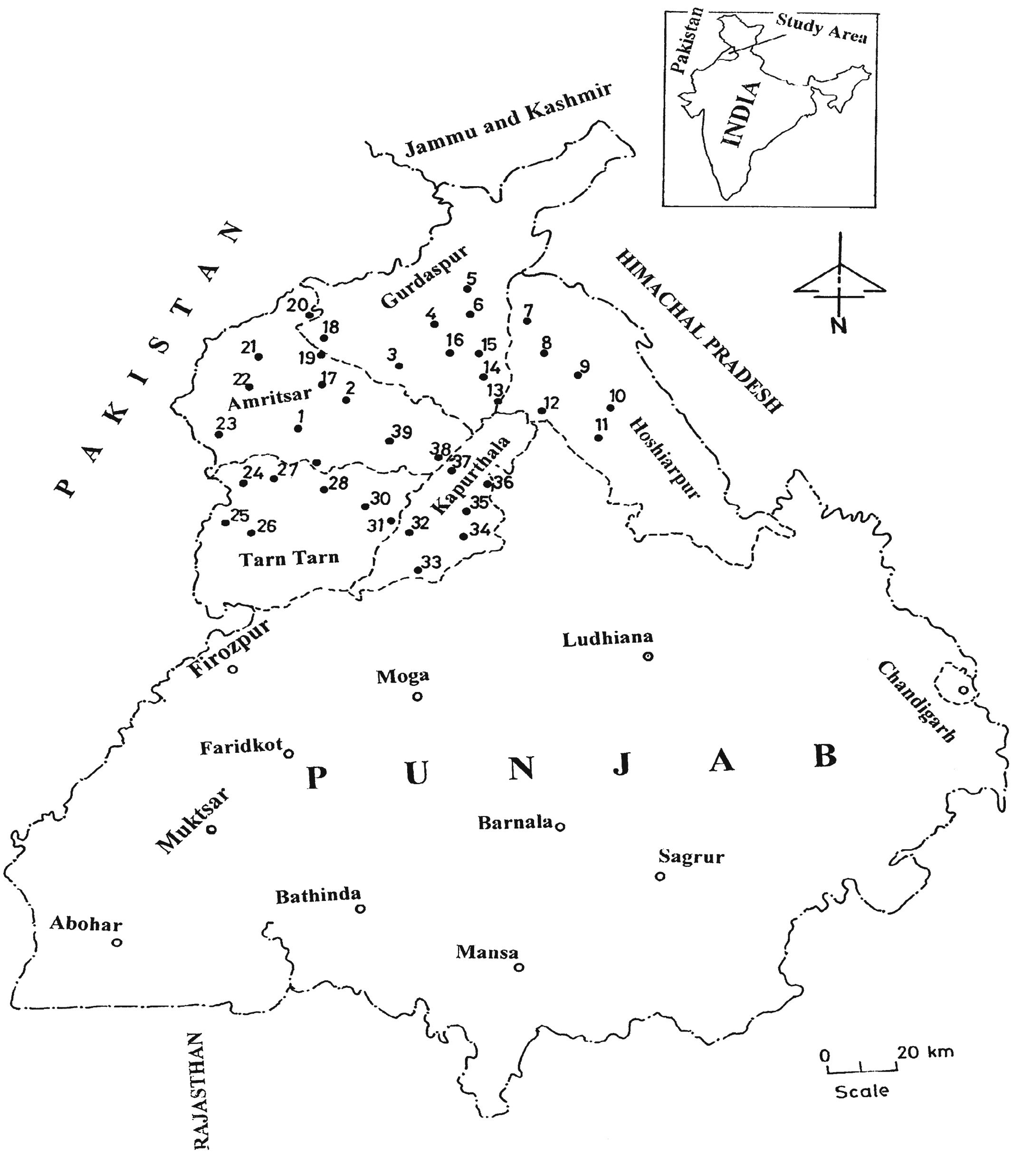


Fig. 1 Map showing the area surveyed during the present investigations

Geology of the area

Punjab extends from the latitudes 29.30° north to 32.32° north and longitudes 73.55° east to 76.50° east. It is bounded on the west by Pakistan, on the north by Jammu and Kashmir, on the north-east by Himachal Pradesh, and on the south by Haryana and Rajasthan. Due to the presence of a large number of rivers, most of the Punjab is a fertile plain. The southeast region of the state is semi-arid and gradually presents a desert landscape. A belt of undulating hills extends along the northeastern part of the state at the foot of the Himalayas. Our study area consists of five districts of Punjab, viz. Amritsar, Tarn Taran, Gurdaspur, Hoshiarpur, and Kapurthala (Fig. 1).

Amritsar is located in Punjab state of India between 31.63° N and 74.86° E latitudes. Ideally located in the northwest part of India, Amritsar lies amid River Beas (to the east) separating Amritsar from Kapurthala and River Ravi (to the west). It is located in the lower part of Upper Bari Doab. It is very interesting that river Beas joins Satluj River at the confluence of Lahore (Pakistan), Firozpur, Amritsar, and Kapurthala. Amritsar has alluvial deposits brought by Beas and Ravi Rivers.

Gurdaspur is located at 32.03° N 75.52° E. It has an average elevation of 242 m (793 ft). It is bounded on the north by the Jammu region of Jammu and Kashmir, Chamba; on the east by Kangra district and the Beas River; on the south by Amritsar district; and on the west by Sialkot and occupies the submontane portion of the Ban Doab or tract between the Beas and the Ravi River.

Kapurthala is located at 31.38° N 75.38° E, about 20 km (12 miles) from Jalandhar. Its average elevation is 225 m (740 ft).

Hoshiarpur is located at 31.53° N 75.92° E. It has an average elevation of 296 m (971 ft). Hoshiarpur district is located in the northeast part of the Indian state of Punjab. The Punjab sediments are derived from Himalayas, and the soil is alluvium in nature.

Experimental technique

Alpha-logger technique for soil gas measurements

The radon concentration in soil-gas is measured with a specially designed soil gas unit by connecting the AlphaGUARD, Alpha-Pump, and a modified STITZ-soil-gas probe (Fig. 2). The sampling of soil gas radon in the study area is done in the month of April 2009. The layout at each sampling location is shown in Table 1. The AlphaGUARD is operated in the flow mode to

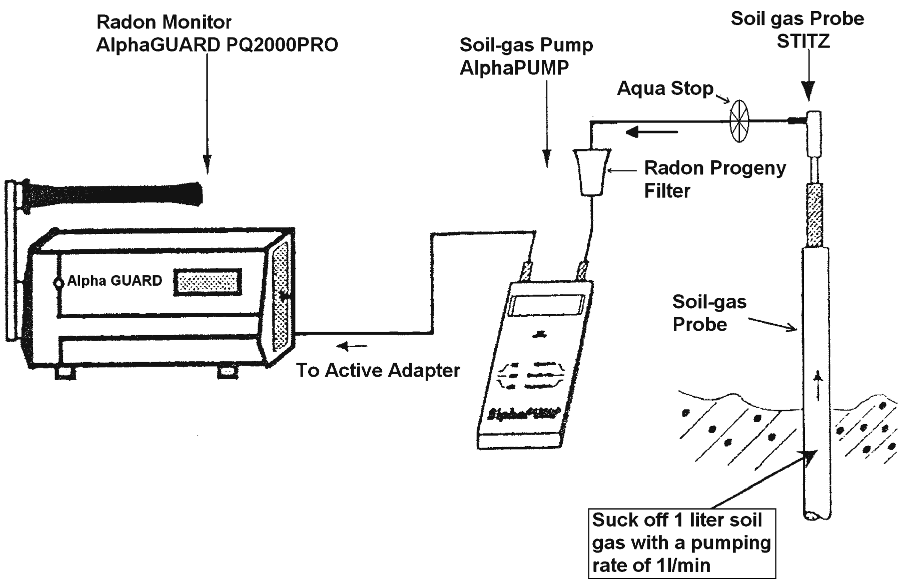


Fig. 2 AlphaGUARD radon monitoring in soil gas

Table 1 Values of radon concentration in soil gas samples from different locations in Northern Punjab

S. no.	Number of sample	Location of sample	Latitude and altitude	Temperature °C	Pressure (mbar)	Humidity (%)	Mean radon concentration (KBq/l)	Standard deviation
1	3	Amritsar	31.78 N 75.15 E 235 m	40	977	19	1.5	0.02
2	3	Kathunagal	31.71 N 75.01 E 238 m	27	982	51	21.5	0.2
3	3	Batala	31.7 N 75.15 E 249 m	28	982	79	3.19	0.006
4	3	Dhariwal	31.95 N 75.32 E 248 m	34	979	31	13.1	0.1
5	3	Gurdaspur	32.02 N 75.38 E 265 m	33	979	40	34.1	0.1
6	3	Satheali	31.90 N 73.42 E 248 m	40	977	23	1.23	0.006
7	3	Mukerian	31.95 N 75.59 E 236 m	39	979	29	2.93	0.06
8	3	Dasuya	31.80 N 75.66 E 275 m	31	977	65	25.0	1
9	3	Garhdiwala	31.74 N 75.74 E 282 m	28	974	73	18.9	0.2
10	3	Haryana	31.64 N 75.83 E 289 m	26	972	79	7.10	0.1
11	3	Ghorewah	31.63 N 75.71 E 255 m	34	973	35	3.3	0.1
12	3	Tanda	31.66 N 75.65 E 228 m	37	974	27	14.2	0.1
13	3	Shri Hargobind pur	31.2 N 75.46 E 254 m	38	972	28	12.9	0.1
14	3	Harchowal	31.23 N 75.70 E 252 m	38	972	29	9.9	0.1
15	3	Quadian	31.81 N 75.36 E 242 m	38	971	27	6.7	0.2
16	3	Wadala Granthian	31.21 N 75.30 E 241 m	42	971	22	2.5	0.1
17	3	Majitha	31.76 N 74.95 E 232 m	32	982	39	1.9	0.06

Table 1 (continued)

S. no.	Number of sample	Location of sample	Latitude and altitude	Temperature °C	Pressure (mbar)	Humidity (%)	Mean radon concentration (KBq/l)	Standard deviation
18	3	Kala Afgana	31.87 N 75.03 E 232 m	36	981	31	1.4	0.1
19	3	Fathegarh Churian	31.86 N 74.95 E 236 m	34	981	35	0.5	0.01
20	3	Ramdass	31.78 N 74.65 E 231 m	35	989	35	12	0.06
21	3	Ajnala	31.85 N 74.69 E 232 m	32	981	32	11	0.6
22	3	Chougawan	31.71 N 74.66 E 226 m	32	981	37	23.7	0.1
23	3	Attari	31.8 N 74.6 E 215 m	31	981	41	32.5	0.1
24	3	Nushera Dhala	31.49 N 74.64 E 205 m	31	982	77	35.8	0.1
25	3	Khalra	31.39 N 74.62 E 225 m	29	981	49	14.5	0.1
26	3	Bhikhiwind	32.34 N 74.68 E 215 m	28	982	56	3.4	0.2
27	3	Chabaal	31.5 N 74.79 E 218 m	35	978	33	2.0	0.06
28	3	Tarn Taran	31.4 N 74.95 E 218 m	33	980	47	7.1	0.06
29	3	Chabba	31.5 N 74.8 E 219 m	32	979	35	23.9	0.06
30	3	Vain Poin	31.41 N 75.04 E 229 m	34	980	27	1.0	0.01
31	3	Goindwal Sahib	31.36 N 70.14 E 224 m	36	980	28	1.0	0.01
32	3	Talwandi Choudrian	31.29 N 75.18 E 205 m	35	981	30	0.3	0.01
33	3	Sultanpur Lodhi	31.22 N 75.1 E 261 m	37	980	19	1.6	0.2
34	3	Karhlan Kalan	31.29 N 75.21 E 298 m	37	979	28	14.9	0.2

Table 1 (continued)

S. no.	Number of sample	Location of sample	Latitude and altitude	Temperature °C	Pressure (mbar)	Humidity (%)	Mean radon concentration (KBq/l)	Standard deviation
35	3	Shekhupur	31.29 N 75.31 E 214 m	40	977	21	5.9	0.1
36	3	Subhanpur	31.46 N 75.41 E 248 m	39	976	19	1.1	0.1
37	3	Dhilwan	31.40 N 75.42 E 239 m	39	977	20	1.3	0.01
38	3	Beas	31.50 N 75.31 E 223 m	34	976	27	8.8	0.01
39	3	Khilchian	31.55 N 75.19 E 237 m	38	975	21	1.9	0.02

measure radon concentration levels in soil. The main advantages of the AlphaGUARD are its fast response, higher sensitivity and a wide dynamic range which is linear over the interval 2–2 × 10^6 Bq m^{-3}.

By connecting The AlphaGUARD PQ2000PRO, AlphaPUMP, and a modified STITZ-soil gas probe, a complete soil gas measuring system was created. The system allows spot measurements as well as continuous soil gas monitoring. For exact soil gas measurements where also high concentration gradients shall be portrayed correctly, the AlphaGUARD has to be set to the flow-through mode. The soil gas probe consists of a drilling rod with an exchangeable drilling tip with air-lock which is closed by a rivet and capillary probe. By means of a protective or machine hammer, the drilling rod can be hit into the ground, and a hole 1-m deep was drilled. Afterwards, the drilling rod has to be drawn up 2–3 cm. The capillary probe is inserted into the drilling rod and pushed forward until a firm stroke is noticed. Herewith, the capillary probe penetrates the air-lock and pushes the rivet out of the tip of the probe. By this, the opening for sucking the air in becomes free. With the AlphaPUMP and radon progeny filters connected in series, soil gas is sucked out of the

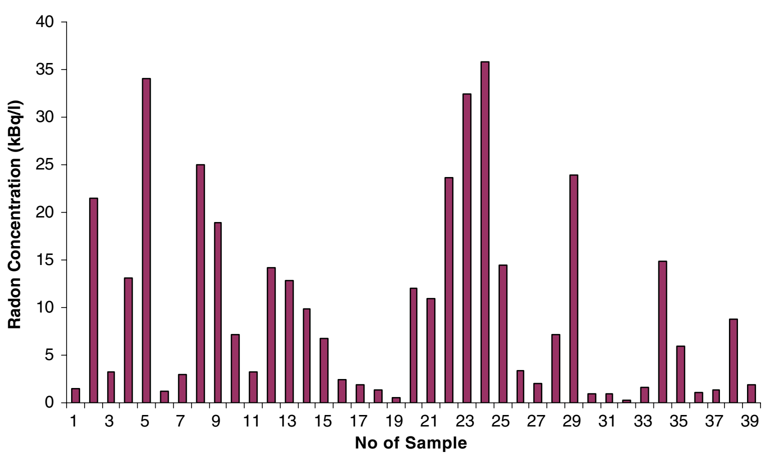


Fig. 3 Variation of radon concentration with number of samples

Table 2 Correlation of radon concentration in soil gas with meteorological parameters

Parameter	Correlation coefficient
Radon and temperature	−0.4
Radon and pressure	0.2
Radon and humidity	0.4

surrounding ground area through the capillary probe and pressed into the ionization chamber of the AlphaGUARD monitor (Fig. 3). The air-lock integrated in the probe tip enables the capillary probe to be driven in and out as in the respective measuring depth without atmospheric air getting into the tip of the probe. In order to determine only radon ^{222}Rn concentration, the ionization chamber was kept closed tightly after filling it with soil gas for about 10 min—time needed for thoron (^{220}Rn) to decay.

Results and discussion

The soil gas sample locations from different parts of Northern Punjab are shown in Fig. 1. The values of radon concentration in soil gas samples from different locations in the study area are given in Table 1. The radon concentration in soil varies from 0.3 to 35.8 kBq/l. The minimum value is observed in Talwandi Choudhrian and maximum in Nushera Dhala. The higher value of radon in the soil gas from Nushera Dhala may be due to the fact that this location is close to rivers Beas and Satluj that the moisture content may enhance the radon level in the sample (Singh and Virk 1996). Figure 3 shows the variation of radon concentration at different locations.

The results obtained by different researchers showed that the soil gas radon concentration may vary over a wide range depending on weather conditions, climatic factors, and soil type (Durrani and Ilic 1997; Chernik et al. 2001). The high value of radon in soil gas of Gurdaspur area may be due to its closeness to Himachal Himalayas, known for radioactive zones (Kaul et al. 1993). The radon content of soil gas was not directly a function of the radium and uranium concentration of the soil. The variations in the soil gas radon may be due to the factors that include the radium content and distribution, the porosity, the moisture content and density of soil, the underlying bedrocks, and meteorological effects (barometric pressure, rain, etc.) (King 1986).

The correlation between radon concentration with meteorological parameter temperature, pressure, and humidity is evaluated (Table 2). The negative correlation (−0.4) has been observed between radon concentration and temperature, whereas positive correlation 0.2 and 0.4 has been observed between radon concentration with pressure and relative humidity, respectively. The scatter plots of radon vs. temperature, radon vs. pressure, and radon vs. relative humidity are shown in Figs. 4, 5, and 6, respectively.

The result of soil gas radon concentration is compared with the radon concentration in water studied in the similar area by the authors (Singh

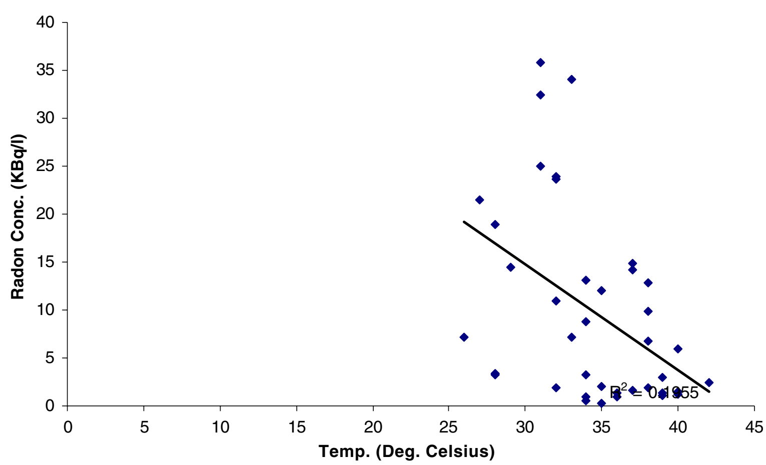
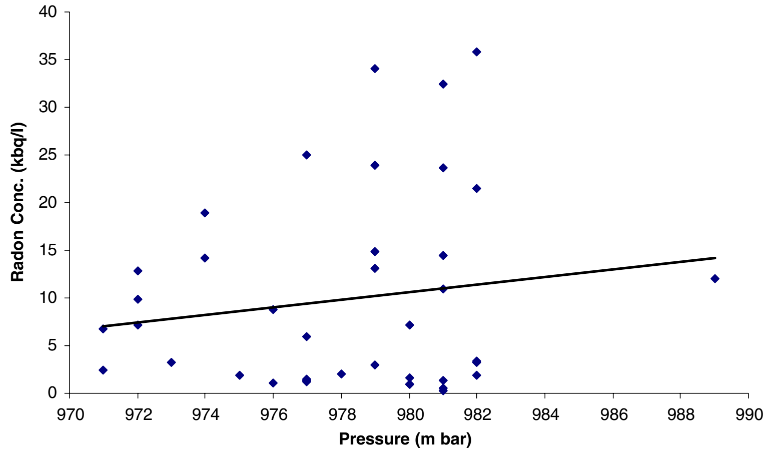


Fig. 4 Radon concentration vs. temperature

Fig. 5 Radon concentration vs. pressure



et al. 2009a). The radon concentration in water obtained by the authors was found to vary from 0.42 to 38.0 Bq/l. The similar trend of radon concentration in soil gas and ground water has been observed except for a few samples. The radon concentration in soil gas of the study area is slightly higher than the radon concentration in soil gas of Ropar district of Punjab by Singh et al. (2009b) (11.6 to 27.4 kBq/m^3) but lower than those reported for soil gas in Himachal Pradesh by Singh et al. (2006) (1.1 to 82.2 kBq/m^3). The higher value in Himachal Pradesh may be due to the presence of active lineaments and faults (Dhar et al. 2003) and presence of uranium mineralization in some areas of the state (Kaul et al. 1993; Singh et al. 2006). Overall, the radon values in the soil gas of Northern Punjab are low and not significant for uranium prospection. Moreover, these values seem to be safe from the health hazards point of view.

Conclusion

With few exceptions, the levels of radon in soil gas in Northern Punjab in general are low and are not significant for uranium prospection. The radon values in soil gas in the study area are lower than those reported in some zones of the neighboring state of Himachal Pradesh and thus seem to be safe from the health aspects.

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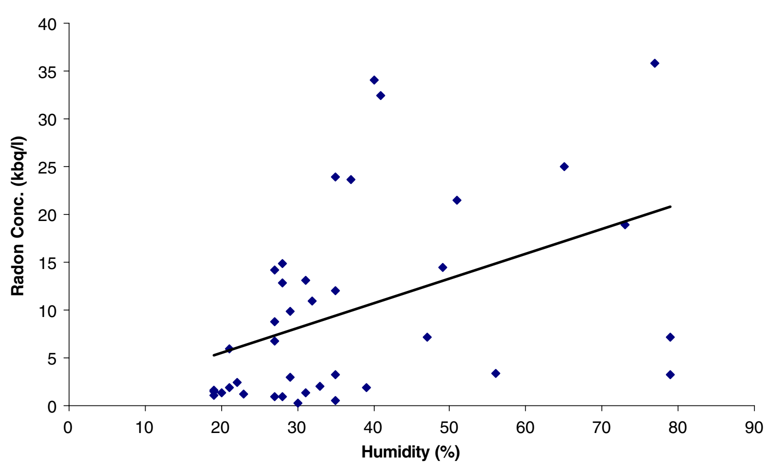
Fig. 6 Radon concentration vs. relative humidity



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