



Radon in groundwater of eastern Doon valley, Outer Himalaya

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Received 21 October 2002; received in revised form 28 February 2003; accepted 12 May 2003

Abstract

The radon content in water may serve as a useful tracer for several geohydrological processes. The hydrodynamic factor, presence of radium in host rocks, as well as the soil porosity and permeability control its concentration in groundwater. In order to understand the factors that control the occurrence of radon in groundwater of Doon valley in Outer Himalaya, a total of 34 groundwater samples were collected from handpumps and tubewells covering three hydrogeological units/areas in the eastern part of Doon valley. Radon variation in tubewells and handpumps varies from 25.4 ± 1.8 to 92.5 ± 3.4 Bq/l with an average of 53.5 ± 2.6 Bq/l. A significant positive correlation between radon concentration and depth of the wells was observed in the Doiwala–Dudhli and Jolleygrant areas suggesting that radon concentration increases with drilling depth in areas consisting of sediments of younger Doon gravels, whereas samples of the Ganga catchment show negative correlation. The high radon levels at shallower depths in the Ganga catchment (consisting of fluvial terraces of Ganga basin) indicate uranium-rich sediments at shallower depth.

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Keywords: Radon; Hydrology; Hydrogeology; Himalaya; Doon valley

1. Introduction

Radon is a radioactive gas that occurs naturally in groundwater as an intermediate step in the decay of uranium (^{238}U) to lead-206 (^{206}Pb). Uranium decays through a number of steps to radium-226 (^{226}Ra), which decays to radon (^{222}Rn) from minerals and rocks. During its migration towards land surface, it may be easily dissolved in groundwater. The high level of radon in groundwater results from radium present in the rocks through which groundwater flows. Therefore, it is not necessary that a high concentration of uranium in the surrounding rocks is the only source for higher radon in water (Dickson, 1990). Other factors, like intensity of joining, presence of shear zones, degree of metamorphism, soil porosity, uranium mineralization, have been found to influence radon concentration in groundwater. Efforts

have been made by various researchers to correlate radon concentrations with factors such as geology, soil porosity, shears, thrust, faults, uranium mineralization, etc. (Choubey and Ramola, 1997; Choubey et al., 1994,2000a,2001,2002; Fleischer and Mogro-Campero, 1978; Kies, 1996; LeGrand, 1987; Mogro-Campero and Fleischer, 1977; Otton, 1992; Przylibski, 2000; Senior and Vogel, 1995; Veeger and Ruderman, 1998; Wiegand, 2001). In a geological environment, radon concentrations generally differ among different rock types and can vary considerably within the same geological group. Radon moves from its source in rocks and soil through voids and fractures and can dissolve in groundwater. Several studies show that, in areas where surface water infiltrates to aquifers, radon may be used as a natural tracer for qualitative investigations. For the estimation of groundwater residence time, it has so far been of limited use, due to its short half-life (Hoehn and Gunten von, 1989; Hamada and Komae, 1994).

In this paper we have measured radon, radium and other water parameters in several water samples in the eastern part of Doon valley to understand the effects that geomorphol-

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1 ogy, lithology and hydrology have on radon concentration
 2 in groundwater.

3 **2. Geological setup**

4 The synclinal trough-shaped Doon valley bounded by
 5 the precambrian rocks of the Lesser Himalayan formations
 6 in the north and Tertiary Siwalik in the south, forms a
 7 part of the sub-montane region of the Garhwal Himalaya
 8 (Fig. 1).

9 The Proterozoic-Cambrian rocks of Lesser Himalaya occur
 10 in the northwest and northeastern part of Doon valley.
 11 Lesser Himalaya formation consists of phyllites, quartzite
 12 shales, sandstone, greywacks, calcareous shales, dolomite
 13 and limestone, whereas the central part of the valley is
 14 filled with coarse elastic fan deposits of late Pleistocene and
 15 Holocene age known as Doon gravels. The Siwalik range
 16 in the south of Doon valley is subdivided into lower, middle
 17 and upper horizons. Lower and middle Siwalik consists
 18 of friable medium-grained sandstones, rich in micaceous
 19 minerals; however, the upper Siwaliks mainly contain

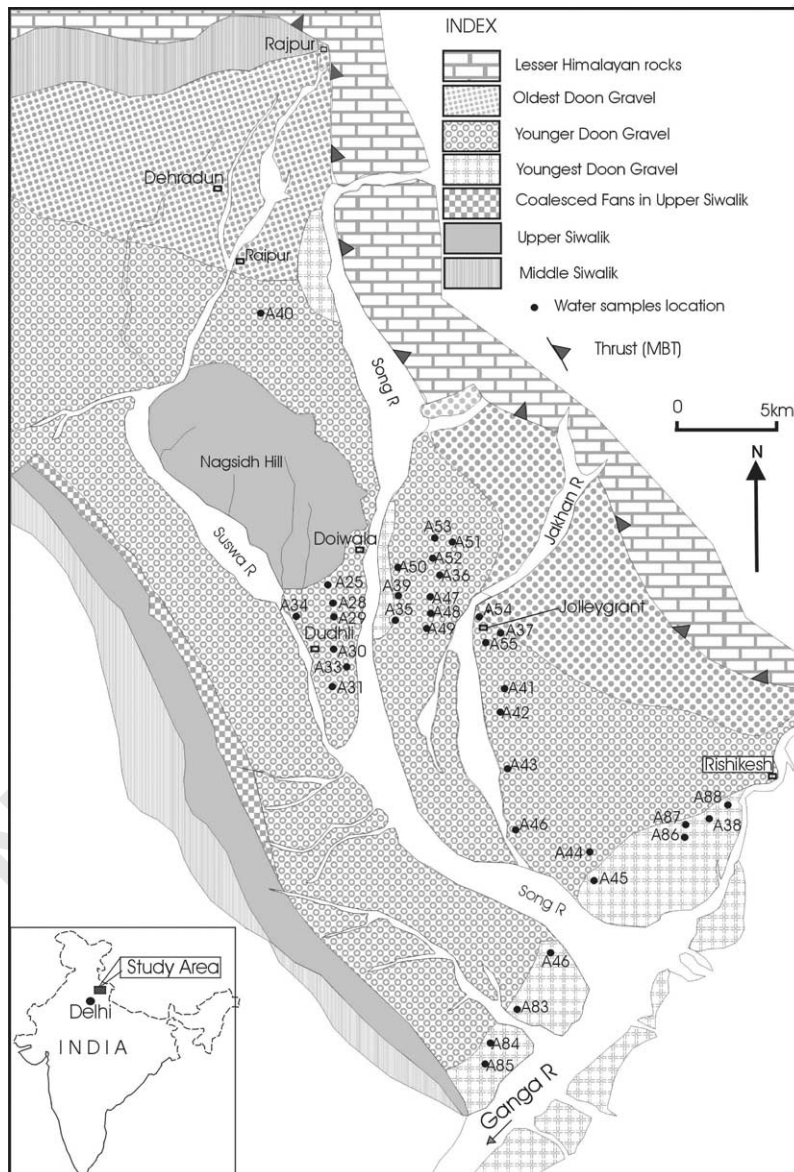


Fig. 1. Geological map of a part of Doon valley (after Bartarya, 1995) showing radon sampling sites.

conglomerates consisting of white, pink and grey quartzite, granite and phyllite boulders and pebbles. Geohydrologically, the structural controlled intermontane Doon valley is divisible into three zones i.e. Lesser Himalayan Zone, Synclinal Central Zone and Siwalik Zone. (Bartarya, 1995):

3. Experimental procedure

A total of 34 water samples were collected (24 from tubewells and 10 from handpumps) and analysed for radon concentration. All these water sources are used for domestic and for irrigation purposes. The sampling sites for radon measurements studies were tubewells and handpumps for which precise information on depth and casing lengths are available and are easily accessible. Water samples from the tubewells/handpumps were measured for radon during the month of July–August and the weather conditions during the sampling period were fairly stable. Water was collected after running tubewells and handpumps for about 10 min. This procedure was adopted to avoid the mixing of radon present in the casing.

For radon measurement, a 750 ml water sample was put in an air-tight conical flask of 1 l capacity connected to a close circuit with a ZnS coated detection chamber through a hand-operated rubber pump and a glass bulb containing CaCl_2 to absorb the moisture. Air was then circulated in a closed circuit for a period of 10 min till the radon formed a uniform mixture with the air and the resulting alpha activity was recorded. The calibration factor and efficiency of the detectors used in the present study are discussed in detail in Choubey et al. (2000a,b) and Singh et al. (1986). The radium content in water samples was determined by measurements of radon produced by radium in water. For this purpose, the water samples were de-emanated in the laboratory and then sealed for about 1 month. After that the radon concentration was measured using ZnS coated detection chamber.

The pH, temperature and conductivity of the water samples were measured in the field using a portable water-analysis kit. The stability and precision of the measurements were found to be nominal and are well within 5% of the mean of data for pH, temperature and conductivity. However, the error for measurement of the depth of static water level is slightly higher and seldom exceeds 10%.

4. Results and discussion

Radon and ^{226}Ra concentration, depth of the wells, temperature, pH and conductivity of water in tubewells and handpumps in different hydrogeologic units/areas are shown in Table 1 and locations of water samples in Fig. 1.

Radon concentration in 34 shallow to deep (7–156 m) tubewells and handpumps varies from 25.4 ± 1.8 to 92.5 ± 3.4 Bq/l with an average of 53.5 ± 2.6 Bq/l and geometric mean 51.5 ± 2.6 Bq/l. The highest radon concen-

tration was found in the Doiwala–Dudhli area, whereas, a few higher radon values were also found in the Jolleygrant and Ganga catchment areas. The higher values were observed both in tubewells and handpumps. Therefore, radon data for both the tubewell and the handpump were treated similarly.

In addition to radon and ^{226}Ra other physicochemical parameters of water like temperature, pH and conductivity were also measured in order to find the impact of these parameters on radon concentration. However, no correlation was found between radon concentration and temperature, pH and conductivity. Also, no overall correlation could be established when radon concentration of all the water samples was plotted against the depth of the wells. This is mainly due to the fact that the samples come from different geohydrological units having distinct characteristics. Further, the lack of correlation may also be due to the mixing of groundwater from different levels of aquifers (Choubey et al., 2002). In order to understand the control of geohydrological characteristics on the radon emanation in groundwater, the study area has been sub-divided into three hydrogeologic units/areas depending upon the aquifer characteristics, flow-path, geomorphic features and lithological composition of the aquifer. These are Doiwala–Dudhli, Jolleygrant and Ganga catchment units. In this way depth of the well and radon concentration showed linear relationships (Fig. 2).

Radon concentration vs. depth of the wells in hydrological units of Doiwala–Dudhli and Jolleygrant areas shows positive correlation $r^2 = 0.67$ and 0.63 , respectively (Fig. 2). Geologically, all the samples of the above units are located in the younger Doon gravels that consists of a poorly sorted mixture of clay, sands, gravels and large boulders of quartzite and sandstone. These appear to have been derived from the Lesser Himalayan formations to the north and Siwalik formation in the south. Because of heterogeneous lithology and highly porous Doon gravels, the radon emanated is easily dissolved in infiltrated water ultimately reaching the underground water. The greater depth of the well allows more water to interact with greater thickness of the aquifer. The bigger residence time and larger surface area/volume ratio of the well (Choubey et al., 2000a,b) will result in higher radon with increasing depth.

Radon concentration in seven water samples of the Ganga catchment varies from 39.3 ± 2.3 to 69.6 ± 3 Bq/l with an average of 57.1 ± 2.7 Bq/l. The plots of radon concentration vs. depth (Fig. 2), in case of samples present along the terrace deposits of the Ganga and Song rivers show a strong negative relationship ($r^2 = 0.81$) indicating that higher radon concentrations are present at shallow depths. Field relationship and the lithologies of the wells indicate that aquifers of this area consist of at least two layers. One deep water bearing strata comprising sand gravel and boulders mainly deposited by the Song river and derived from the rocks present in the catchment of Doon valley. These gravel

Table 1
Radon, radium and other measured parameters of water samples in different hydrological units/areas^a

No.		Radon (Bq/l)	Depth (m)	Temp. (°C)	pH	Conductivity (μS)	Radium (Bq/l)
<i>Doiwala–Dudhli</i>							
A33	Handpump	33.5 ± 2.1	38.1	35	7.0	475	0.10 ± 0.02
A34	Handpump	42.6 ± 2.4	17.0	23.7	6.8	390	
A35	Handpump	40.7 ± 2.3	42.7	22	7.6	459	
A39	Handpump	66.1 ± 3.0	48.8	25	7.2	238	0.34 ± 0.05
A25	Tubewell	92.5 ± 3.4	78.0	22.8	6.9	430	
A28	Tubewell	85.9 ± 3.1	106.4	23.55	7.5	560	
A31	Tubewell	69.9 ± 2.9	90.0	24.9	6.9	360	
A30	Tubewell	67.8 ± 3.0	87.8	22.5	6.6	188	
A29	Handpump	50.0 ± 2.7	38.8	22.3	7.2	508	0.34 ± 0.05
<i>Jolleygrant area</i>							
A40	Handpump	72.3 ± 3.1		21.5	6.4	240	
A43	Handpump	43.9 ± 2.4	51.9	23.1	6.8	288	
A44	Handpump	45.0 ± 2.4	55.0	23.8	6.8	294	
A45	Handpump	34.3 ± 2.1	28.0	25.5	7.1	328	
A46	Handpump	25.4 ± 1.8	7.0	26.4	6.6	540	
A36	Tubewell	53.9 ± 2.7	115.0	22	6.4	160	
A37	Tubewell	53.9 ± 2.7	130.0	23.9	7.2	169	0.68 ± 0.01
A41	Tubewell	37.0 ± 2.2	103.0	23.8	6.6	328	0.34 ± 0.05
A42	Tubewell	38.0 ± 2.2	90.0	25.1	7.1	284	
A47	Tubewell	52.8 ± 2.6	121.3	23.3	7.5	208	0.77 ± 0.12
A48	Tubewell	40.6 ± 2.3	114.0	23.1	7.3	231	
A49	Tubewell	43.7 ± 2.4	65.0	22.7	6.4	268	0.56 ± 0.08
A50	Tubewell	49.5 ± 2.6	91.5	25.1	6.7	257	0.61 ± 0.09
A51	Tubewell	58.6 ± 2.8	110.0	22.4	6.6	173	0.64 ± 0.10
A52	Tubewell	43.2 ± 2.4	101.0	24	7.6	176	0.47 ± 0.07
A53	Tubewell	62.0 ± 2.9	125.0	24.7	7.5	199	
A54	Tubewell	56.6 ± 2.7	130.0	25.1	7.4	175	0.84 ± 0.13
A55	Tubewell	59.3 ± 2.8	156.0	23.1	7.4	168	
<i>Ganga catchment</i>							
A38	Tubewell	64.7 ± 2.7	30.5	25	7.2	238	
A83	Tubewell	51.9 ± 2.6	66.0	24.5	7.0	264	
A84	Tubewell	52.7 ± 2.6	91.5	24.3	7.3	308	0.62 ± 0.09
A85	Tubewell	69.6 ± 3.0	7.6	24.8	6.9	792	
A86	Tubewell	59.3 ± 2.8	21.3	25.2	6.3	237	
A87	Tubewell	39.3 ± 2.3	100.0	24.3	7.0	278	
A88	Tubewell	62.5 ± 2.9	45.7	24.5	7.1	279	0.76 ± 0.11

^aUncertainty of measurements for temperature, pH and conductivity < 5% and for depth < 10%.

1 deposits, called Younger Doon gravel, have very high
 2 porosity and permeability but are poor in uranium-rich
 3 minerals. The other shallow aquifers comprising sand with
 4 occasional pebbles and clay have relatively low porosity
 5 and permeability. These are mainly derived from the erosion
 6 of the crystalline rocks of Lesser and Higher Himalaya and
 7 are rich in uranium containing minerals. The uranium-rich
 8 minerals associated with sand and long residence time of
 9 water in the shallow aquifer is possibly responsible for
 10 higher radon concentration at shallow depth. The higher
 11 permeability of Younger Doon gravels do not allow water to

interact with the surrounding rocks/sediments. Besides, the
 boulders (quartzite and sandstone) and pebbles present in
 this zone are mostly from the Lesser Himalaya formations
 present in the Doon valley that are poor in uranium.

The 13 water samples were also analysed in the laboratory
 for ²²⁶Ra measurements. The radium content was found to
 vary from 0.10 ± 0.02 to 0.84 ± 0.13 Bq/l with an average of
 0.54 ± 0.08 Bq/l. The higher values of radium were observed
 in the Jolleygrant and Ganga catchment areas. Overall, no
 significant correlation ($r^2 = 0.31$) was found between radon
 and radium in the water samples.

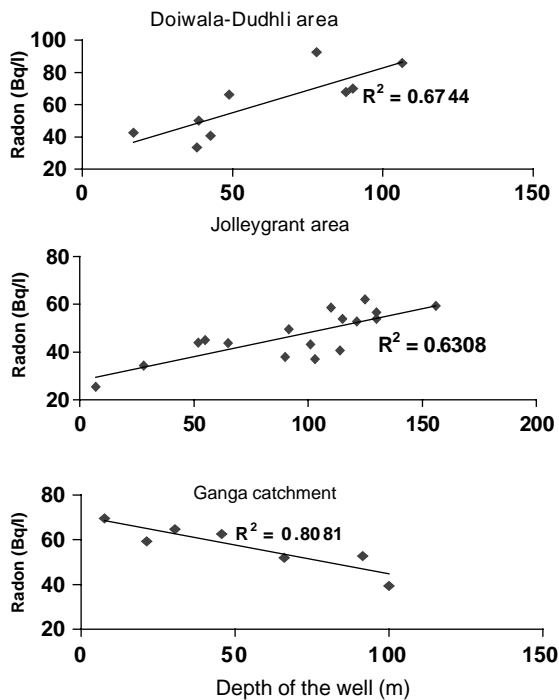


Fig. 2. Plots of radon vs. depth of water wells in different hydrogeological areas.

Acknowledgements

The authors are grateful to the Director, Wadia Institute of Himalayan Geology, Dehradun, for providing the necessary facilities to carry out this work.

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