Measurement of radon concentration in groundwater using RAD7 in Roorkee area of Uttarakhand, India

Pankaj Garg[1], Gopal Krishan[1*] and Sudhir Kumar[1]

National Institute of Hydrology, Roorkee-247667, Uttarakhand, India
Email: drgopal.krishan@gmail.com

Abstract

Among natural radiations, radon (^{222}Rn) has a significant contribution to affect the mankind. Radon is generated in rock and soil and it easily dissolves in water and becomes common radiological constituent of groundwater. Groundwater may contain high concentrations of radon. In the present study, radon activity concentrations were measured in 12 representative groundwater samples collected from tube-wells/handpumps surrounding the Roorkee area of Uttarakhand, India. The measurements were performed by RAD7, an electron radon detector manufactured by Durridge Company Inc. Radon concentration values in groundwater show a wide variation. The radon concentrations in more than 50% of samples collected from Rampur, Bhagwanpur, Sisona, NIH, Kishanpur, Sherpur, Ibrahimpur and Khajarpur are above the safe limit of 11 Bq L^{-1} recommended by the US Environmental Protection Agency (USEPA). The area needs further detailed investigation and continuous monitoring for determination of radon concentration of groundwater.

Keywords: *Radon; groundwater; Roorkee; Uttarakhand; tubewell/handpump*

1. Introduction

Among natural radiations, radon (^{222}Rn) has a significant contribution to affect the mankind. Radon is generated in rock and soil, emitted from uranium as an intermediate decay product of the Uranium/Thorium radioactive series (ICRP 1993, 1994) and it easily dissolves in water and becomes common radiological constituent of groundwater. Groundwater may contain high concentrations of radon as compared to the surface water such as lakes, ponds and rivers. On abstraction of groundwater from bore wells, due to dissipation of dissolved gases these are escaped into the air under atmospheric pressure and it has noticed that the meteorological parameters have influence on the emanation of radon in the soil and groundwater. Singh et al (1988) and Sharma et al (2000) have found positive correlation of temperature, pressure and wind velocity with radon and negative correlation with humidity and rainfall. Garg et al (2015) have found modest correlation of pH, EC and temperature with radon.

Radon is known to present a risk of lung cancer when it, or rather its decay products, are inhaled. It is now understood that the most important component of the dose comes not from the gas itself, but rather from its short-lived decay products. The ingestion of water which contains particularly high levels of radon can lead to a significant risk of stomach cancer (Hursh et al, 1965). However, the decay products are isotopes of solid elements and will quickly attract to themselves molecules of water and other atmospheric gases. These, in turn, attach to natural aerosol particles. If inhaled, the decay products, whether attached to aerosol particles or ‘unattached’, will largely be deposited on the surface of the respiratory tract and, because of their short half-lives (less than half an hour) will decay there.

Radon concentrations in groundwater have been measured by various workers in various parts of India as: in Rajasthan (Rani et al. 2013), Mysore (Shashikumar et al. 2011), eastern coast of West Bengal (Krishan et al. 2015a), eastern coast of Baleshwar district of Odisha (Krishan et al. 2014a), Dehradun valley, Uttarakhand (Choubey et al. 2001), Haridwar district, Uttarakhand (Garg et al. 2015), Bathinda district of Punjab (Singh et al. 1995). Virk and Singh (1999) have found high radon concentration in river waters of Garhwal and Siwalik Himalayas. Radon concentrations in groundwater can also be used for other applications (Krishan et al., 2015b).

Krishan et al. (2015a) measured ^{222}Rn activity in 20 groundwater samples from East Coast of West Bengal were measured and fond the values of 222Rn ranging between 1.9 ± 0.78 and 9.0 ± 1.13 Bq L-1 with an average value of 5.0 ± 0.83 Bq L-1, well within the EPA's maximum contaminant level of 11.1 Bq L-1 but in another study carried out by Krishan et al (2014a) 222Rn activities were measured in 10 groundwater samples of coastal area of Baleshwar district in Odisha and found the values of 222Rn ranging between 1.6±0.21 and 17.0±1.69 Bq L-1with an average value of 8.98±0.85 Bq L-1, and seven samples were well within the Environmental Protection Agency's maximum contaminant level of 11.1 Bq L-1 while three samples were more than the maximum contaminant level of 11.1 Bq L-1.

In the present study, radon activity concentrations were measured in 12 representative groundwater samples collected from tube-wells/handpumps surrounding the Roorkee area of Uttarakhand, India with a purpose to investigate the radon levels of groundwater being used for drinking as potable water.

1.1 *Study area*

Roorkee as shown in Figure 1 is located in the foot hills of Shiwaliks in the north western part of the Indo-Gangetic plains falling under the latitude 29°52', longitude 77°53' and altitude 268m. The normal rainfall of Roorkee is 1156.4 mm and 86% of this is recorded during monsoon period (June to September). The monthly average maximum temperature range observed between 20.4 - 39.2 and minimum temperature range varied between 10.6 -27.2 (Krishan et al. 2014b).

Roorkee is a part of Gangetic alluvial plains and lithologically, the alluvium is formed of unconsolidated to semi-consolidated deposits of sand, silt, clay and kankar. The ground water conditions in alluvial parts are considerably influenced by the varying lithology of the subsurface formations which has been found in various studies in Punjab (e.g. Chopra and Krishan 2014a, b; Krishan and Chopra 2015; Krishan et al. 2014c-f; Lapworth et al. 2014).

Geologically the area is divided into three zones viz. Shiwaliks, Bhabar and Gangetic Alluvial Plains from North to South. The Shiwalik range forms the outermost part of Himalaya and comprises Tertiary Group of rocks. In Bhagwanpur block only Upper and Middle Shiwaliks are exposed. The Upper Shiwaliks is constituted of boulders, pebbles of quartzites, sand and clay. Middle Shiwaliks comprises mainly grey micaceous sandstone and siltstone. The Bhabar are formed along the foothills of Shiwaliks. Gangetic alluvial plains are in the south of the piedmont plains and lithologically, the alluvium is formed of unconsolidated to semi-consolidated deposits of sand, silt, clay and kankar.

The ground water conditions in alluvial parts are considerably influenced by the varying lithology of the subsurface formations (Chopra and Krishan, 2014a; Krishan and Chopra, 2015; Lapworth et al., 2014, 2015). The fluvial deposits of Indo-gangetic Plains exhibit significant variations, both laterally and vertically. The water levels range from 0.78 to 50.20 m bgl in pre-monsoon period and from 0.64 to 48.56 m bgl during post-monsoon period, respectively (CGWB, 2009). Ground water occurs under unconfined, confined and semi-confined conditions. The aquifers are separated with thick clay with considerable thickness, which act as confining layers. The water level data suggests the presence of multilayer aquifer system.

2. Experimental program

A total of 12 representative groundwater samples were collected from Handpumps/tube wells used for drinking and irrigation purposes in the Roorkee area of Haridwar district in Uttarakhand, India. The location along with coordinates details are shown in table 1. Standard methodology was used to collect the samples. The pH, EC and temperatures were recorded using hand held pH meter, EC meter and thermometers, respectively. The detailed methodology for radon measurement is given by Krishan et al (2015a). Radon concentrations in these samples were measured with RAD7, an electronic radon detector connected to a RAD-H_2O accessory (Durridge Co., USA), within 12 hours of sample collection. Fig. 2 shows the schematic diagram of the RAD H_2O. In the setup, the RAD7 detector was used for measuring radon in water by connecting it with a bubbling kit which enables to degas radon from a water sample into the air in a closed loop. A sample of water was taken in a radon-tight reagent bottle of 250 mL capacity connected in a close circuit with a zinc sulphide coated detection chamber which acts as scintillator to detect alpha activity and a glass bulb containing calcium chloride to absorb the moisture. Air was then circulated in a closed circuit for a period of 5-10 min until the radon was uniformly mixed with the air and the resulting alpha activity was recorded and it directly gives the radon concentration.

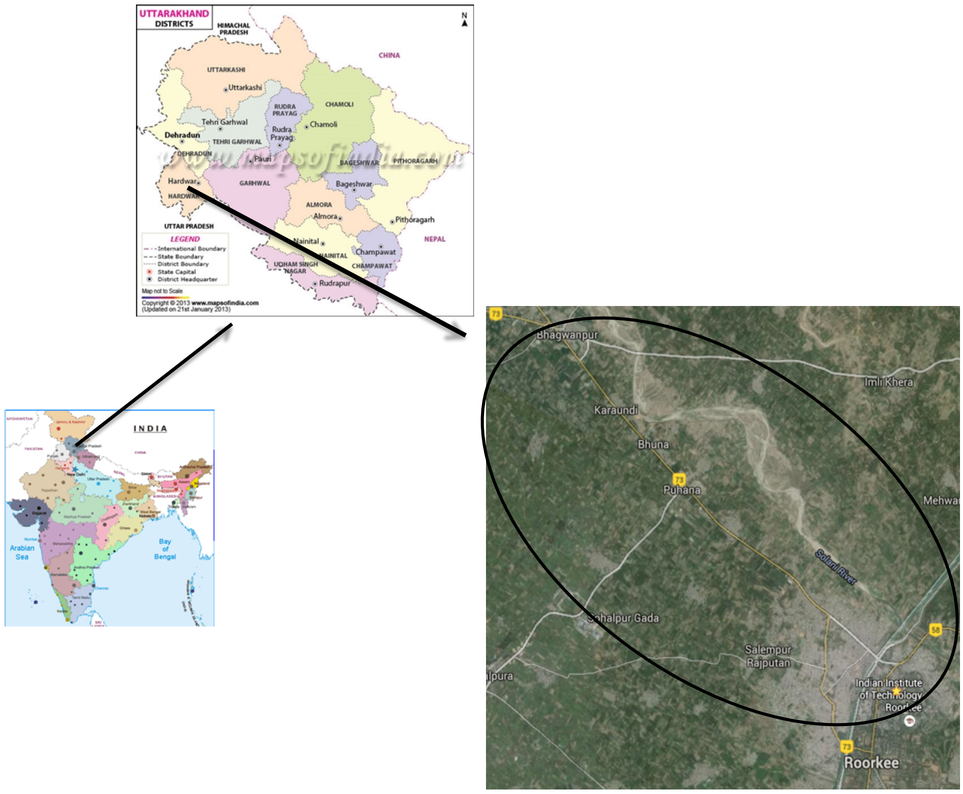

Figure 1 Study area showing Roorkee

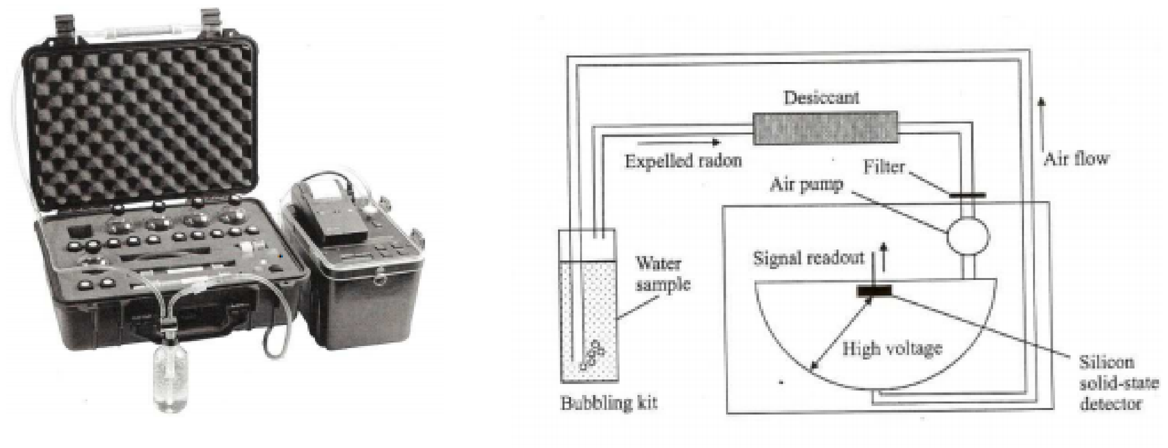

Figure 2 RAD7 connected with RAD7H_2O & accessories

3. Results and discussion

Groundwater is the major source of drinking water in Roorkee. The results for radon concentration in drinking water samples collected from Roorkee area in Haridwar district are reported in Table 1. The values in samples were in the range 1.3 ± 0.5 Bq L^{-1} (Tyagi dairy) to 21.6 ± 2.6 Bq L^{-1} (Rampur) with an average value of 3.70 Bq L^{-1}. The US Environment Protection Agency has proposed that the allowed maximum contamination level (MCL) for radon concentration in water is 11 Bq L^{-1} (USEPA, 1991). The United Nations Scientific Committee on the Effects of Atomic Radiation has suggested a value of radon concentration in water for human consumption between 4 and 40 Bq L^{-1} (UNSCAIR, 2008). Although, the recorded values of radon concentration are within the recommended safe limit of 4-40 Bq L^{-1} (UNSCEAR, 2008) but radon concentration in groundwater at Rampur, Bhagwanpur, Sisona, NIH, Kishanpur, Sherpur, Ibrahimpur and Khajarpur exceeded the safe limit of 11Bq L^{-1} recommended by the US Environmental Protection Agency (USEPA, 1991). The radon concentration at Tyagi dairy, Ramnagar, NIH, IIT and Tehliwala was within the safe limit of 11Bq L^{-1} (USEPA, 1991). When the recorded radon concentration values were compared with the European Commission recommendations on the protection of the public against exposure to radon in drinking water supplies, which recommends the action level of 100 Bq L^{-1} for public water supplies (European Commission, 2001), all the recorded values were found to be well below the action level and hence safe for drinking purposes.

Table 1 Radon concentration in groundwater in Roorkee area

Sample No.	Latitude (N)	Longitude (E)	Location	Sample Depth (m)	Radon concentration in groundwater (Bq L^{-1})				Temperature (°C)
					Min	Max	Mean	SD	
1	29°57'22"	77°48'04"	Sisona	47.24	14.1	16.8	15.3	1.2	29.6
2	29°56'09"	77°48'57"	Bhagwanpur	48.77	15.7	17.8	16.5	0.9	30.2
3	29°54'60"	77°50'07"	Kishanpur	42.67	11.9	14.5	13.0	1.2	29.4
4	29°53'13"	77°52'25"	Rampur	25.91	18.0	24.1	21.6	2.6	30.1
5	29°51'06"	77°52'17"	Tehiliwala	19.81	8.8	10.4	9.4	0.7	28.7
6	29°58'19"	77°53'33"	Ibrahimpur	31.09	10.5	13.9	11.9	1.6	30.1
7	29°51'47"	77°54'27"	Khanjarpur	48.77	11.7	12.0	11.9	0.1	30.4
8	29°52'24"	77°52'55"	Ramnagar	35.05	2.5	4.0	3.3	0.8	23.2
9	29°52'19"	77°53'32"	Tyagi dairy	25.91	0.7	1.8	1.3	0.5	22.8
10	29°52'07"	77°53'39"	NIH	137.16	13.2	15.8	15.0	1.2	21.5
11	29°51'39"	77°53'33"	IIT	44.20	7.7	9.2	8.5	0.6	22.5
12	29°52'52"	77°54'56"	Sherpur	38.10	11.0	13.8	12.6	1.2	24.2

The value of radon concentration obtained in groundwater was compared with those reported by other investigators and it was found that in Iran the values were in the range 0.064-49.088 Bq L^{-1} (Binesh et al., 2010); Cyprus and Greece in the range 0.3-20.0 Bq L^{-1} and 0.8-24.0 Bq L^{-1}, respectively (Nikolopoulos and Louizi, 2008) in Brazil in the range of 0.95-36.0 Bq L^{-1} (Marques et al., 2004); in Pakistan in the range of 2.0-7.9 Bq L^{-1} (Manzoor et al., 2008); in Romania in the range 0.5-129.3 Bq L^{-1} (Cosma et al., 2008).

4. Conclusions

Radon concentration values in groundwater show a wide variation. The radon concentrations in samples collected from Rampur, Bhagwanpur, Sisona, NIH, Kishanpur, Sherpur, Ibrahimpur and Khajarpur are above the safe limit of 11 Bq L^{-1} recommended by the US Environmental Protection Agency (USEPA, 1991). The area needs further detailed investigation and continuous monitoring for determination of radon concentration of groundwater.

Acknowledgement

Authors thank Director, National Institute of Hydrology, Roorkee for all the support and encouragement for the study.

References

Binesh, A, Mohammadi, S, Mowavi, A.A, Parvaresh, P. (2010). Evaluation of the radiation dose from radon ingestion and inhalation in drinking water. *International Journal of Water Resources and Environmental Engineering* 2(7): 174-178.

CGWB, Central Ground Water Board (2009) Ground water scenario of Haridwar District, Uttarakhand. Central Ground, Dehradun.

Chaubey, V.M., Bartarya, S.K., Saini, S.K. and Ramola, R.C. (2001). Radon measurements in groundwater of inter-montane Doonvalley, Outer Himalaya: effects of geohydrology and neotectonic activity. *Environmental Geology*, *40 (3)*, 257-266.

Chopra, R.P.S. and Krishan, Gopal. (2014a). Analysis of aquifer characteristics and groundwater quality in southwest Punjab, India. *Journal of Earth Science and Engineering. 4(10)*, 597-604. http://doi: 10.17265/2159-581X/2014. 10. 001

Chopra, R.P.S. and Krishan, Gopal. (2014b). Assessment of groundwater quality in Punjab. *Journal of Earth Science and Climate Change. 5(10)*, 243. http://dx.doi.org/10.4172/2157-7617.1000243

Cosma, C, Moldovan, M, Dicu, T, Kovacs T. (2008). Radon in water from Transylvania (Romania). *Radiation Measurements, 43*: 1423-1428.

European Commission. (2001). Commission recommendation of 20th December 2001 on the protection of the public against exposure to radon in drinking water. 2001/982/Euratom, L344/85, 2001.

Garg, P.K., Krishan, Gopal and Kumar, Sudhir (2015). Radon concentration in groundwater of Haridwar, Uttarakhand, India. *International Journal of Earth Science and Engineering. 8(2)*, 1-4.

Hursh J B, Morken D A, Davis T P and Lovaas A 1965 The fate of radon ingested by man, *Health Phys*. 11 465–76

International Commission on Radiological Protection (ICRP). ICRP Publication 65: Annals of the ICRP. Vol. 23, No. 2, Pergamon Press, Oxford, 1993.

International Commission on Radiological Protection (ICRP), Protection against 222Rn at home and at work, (Oxford Pergamon Press.), ICRP publication no. 65., 1994.

Krishan, Gopal and Chopra, RPS (2015). Assessment of water logging in south western (SW) parts of Punjab, India-a case study from Muktsar district. *NDC-WWC Journal. 4(1)*, 7-10.

Krishan, Gopal, Rao, M.S. and Kumar, C.P. (2015a). Radon Concentration in Groundwater of East Coast of West Bengal, India. Journal of Radioanalytical and Nuclear Chemistry. 303, 2221-2225.

Krishan, Gopal, Rao, M.S., Kumar, C.P., Kumar, Sudhir, Rao, M. Ravi, Anand. (2015b). A study on identification of submarine groundwater discharge in northern east coast of India. Aquatic Procedia. 4: 3-10.

Krishan, Gopal, Rao, M.S. and Kumar, C.P. (2014a). Estimation of Radon concentration in groundwater of coastal area in Baleshwar district of Odisha, India. Indoor and Built Environment. DOI: 10.1177/1420326X14549979.

Krishan, Gopal, Rao, M.S., Kumar, C.P. and Kumar, Bhishm. (2014b). Isotopic Observations from two stations of North India to investigate geographical effects on seasonal air moisture. Journal of Earth Science and Climate Change. 5, 2. http://dx.doi.org/10.4172/2157-7617.1000180

Krishan Gopal, Lapworth D. J., Rao M. S., Kumar C. P., Smilovic M. and Semwal P. (2014c). Natural (Baseline) Groundwater Quality In The Bist-Doab Catchment, Punjab, India: A Pilot Study Comparing Shallow and Deep Aquifers. *International Journal of Earth Sciences and Engineering, 7 (01)*, 16-26.

Krishan, Gopal, Rao, M.S., Loyal, R.S., Lohani, A.K., Tuli, N.K., Takshi, K.S., Kumar, C.P., Semwal, P and Kumar Sandeep. (2014d). Groundwater level analyses of Punjab, India: A quantitative approach. *Octa Journal of Environmental Research. 2(3)*: 221-226.

Krishan, Gopal, Rao, M.S., Kumar, C.P., Garg, Pankaj and Semwal, Prabhat. (2014e). Assessment of salinity and groundwater quality with special emphasis to fluoride in a semi-arid region of India. *Journal of Earth Science and Climate Change. 5(6)*: 149. http://dx.doi.org/10.4172/2157-7617.S1.016

Krishan, Gopal, Rao, M.S., Lohani, A.K., Kumar, C.P., Takshi, K.S., Tuli, N.K., Loyal, R.S. and Gill, G.S. (2014f). Assessment of groundwater level in southwest Punjab, India. Hydraulics, Water resources, Coastal & Environmental Engineering-Hydro 2014 (Editors: H.L. Tiwari, S. Suresh, R.K. Jaiswal) Excellent Publishing House, New Delhi. 23: 248-254.

Lapworth DJ, MacDonald AM, Krishan G, Rao MS, Gooddy DC, Darling WG. (2015). Groundwater recharge and age-depth profiles of intensively exploited groundwater resources in northwest India. Geophysical Reserach Letters, 42, doi:10.1002/2015GL065798

Lapworth, Dan, Krishan, Gopal, Rao, MS, MacDonald, Alan (2014). Intensive Groundwater Exploitation in the Punjab – an Evaluation of Resource and Quality Trends. . Technical Report. NERC Open Research Archive, BGS-UK

Manzoor, F, Alaamer, A.S, Tahir S.N. (2008). Exposures to 222Rn from consumption of underground municipal water supplies in Pakistan. *Radiation Protection Dosimetry*. *130(3)*: 392-396.

Marques, A.L., Santos, W.D., Geraldo, L.P. (2004). Direct measurements of radon activity in water from various natural sources using nuclear track detectors. *Applied Radiation Isotopes, 60*: 801-804.

Nikolopoulos, D, Louizi, A. (2008). A Study of indoor radon and radon in drinking water in Greece and Cyprus: implications to exposure and dose. *Radiation Measurements, 43*: 1305-1314.

Rani, A., Mehra, R., Duggal, V. (2013). Radon monitoring in groundwater samples from some areas of Northern Rajasthan, India, using a RAD7 detector. *Radiation Protection Dosimetry, 4*, 496-501.

Sharma A.K., Walia V., Virk H.S. (2000). Effect of meteorological parameters on radon emanation, *Journal of Geophysics, 21*, 47-50.

Shashikumar, T S, Chandrashekara, M S and Paramesh, L (2011). Studies on Radon in soil gas and Natural radio nuclides in soil, rock and ground water samples around Mysore city. *International Journal of Environmental Science, 1(5)*, 786- 792.

Singh J., Singh L. and Singh, G. (1995). High U-contents observed in some drinking waters of Punjab, India *Journal of Environmental Radioactivity, 26,* 211–222

Singh, M., Ramola, R. C., Singh, S.and Virk, H. S. (1988). The influence of meteorological parameters on soil gas radon. *Journal of Association of Exploratory Geophysics, 9*, 85-90.

Virk, H.S. and Singh, M. (1999). Uranium and radon anomalies in the river system of N-W Himalayas. *Indian Journal of Environment Protection*, *19(10)*, 750-752.

United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR). (2000). Sources and effects of ionizing radiations, volume 1 (United Nations, New York).

USEPA. United States Environmental Protection Agency. (1991). Federal Register 40 Parts 141 and 142 National Primary Drinking Water Regulations; Radionuclides: Proposed Rule. U.S. Government Printing Office, Washington, DC.