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In situ measurements of radon levels in groundwater in Northern Rajasthan, India

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ABSTRACT

Radon gas is a significant health threat linked to thousand of preventable deaths each year. In the present research, radon activity concentrations were measured in 80 groundwater samples collected from 20 villages of the SriGanganagar and Hanumangarh districts of Northern Rajasthan, India. The water samples are taken from Tube wells. The measurements were performed by RAD7 an electronic radon detector manufactured by DURRIDGE COMPANNY Inc. The radon concentration in these samples is found to vary from (1.8 ± 0.7) to (8.2 ± 1.1) Bq L^{-1} with a mean value of 3.87 Bq L^{-1}. These values are compared with the safe limit values recommended for drinking water. The recorded values of radon concentration are within the safe limit of 11 Bq L^{-1} recommended by the US Environmental Protection Agency (USEPA). When the measured radon activity concentration values were compared with the allowed MCL for radon concentration in water for human consumption (4-40 Bq l^{-1}) suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation, it was observed that the recorded values were well within the safe limit.

Keywords: Groundwater, Radon, RAD7, Radiological risk, Tube well

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INTRODUCTION

Radon is a naturally occurring odorless, colorless, tasteless inert gas which is imperceptible to our sense. It is produced continuously from the decay of naturally occurring radionuclide such as U-238, U-235, Th-232. The isotope Rn-222, produced from the decay of U-238, is the main source (approximately 55%) of internal radiation exposure to human life [1]. The radon content in groundwater sources depends in the radium concentration in the rock of the aquifer [2, 3]. Dissolved radon is contained in natural groundwater due to primordial uranium in rocks and soils with which it comes in contact [4]. Human beings are exposed to radon through inhalation and ingestion. Radon monitoring has been increasingly conducted worldwide because of the hazardous effects of radon on the health of human beings. In many situations such as showering, washing clothes and flushing toilets, radon is released from the water and mixes with the indoor air. The radon from water contributes to the total inhalation risk associated with radon in indoor air. Although radon in drinking water does not pose a direct health risk [5]. The exposure of population to high concentrations of radon and its daughters for a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer [6]. However, a very high level of

radon in drinking water can also lead to a significant risk of stomach and gastrointestinal cancer [7]. Many studies have been conducted worldwide to determine its concentration in different environmental media in order to reduce its adverse effects on the human beings [8-13].

Geology of area

Rajasthan is located in northwest of India. It lies between latitude 27^o 00' N and longitude 74^o 00' E. Fig. 1 Shows the geographic location of the state of Rajasthan in India, as well as the location of the sampling sites in Rajasthan. The climate of the study area is marked by the large variation of temperature, extreme dryness and scanty rainfall. November to March is cold season, followed by summer April to June, from July to mid September is monsoon while mid september to October is post monsoon period. Minimum and maximum temperature is 1^o C and 45^o C respectively, while the mean temperature remained 23^o C. The study area is plain and with thick layer of alluvium and windblown sand. The oldest rocks of the area belong to Aravalli Super Groups which includes phyllite, shale and quartz veins. The studied area is bounded on the western side by Pakistan, on the northeast side by Haryana and Punjab to the north. The Ghaggar River is an ephemeral one and has northeast to southeast course near Hanumangarh and divide the Ganganagar district into two halves.

MATERIALS AND METHODS

In the present research, radon activity concentrations were measured in 80 groundwater samples collected from 20 villages of the SriGanganagar and Hanumangarh districts of Northern Rajasthan, India using a RAD7, an electronic radon detector manufactured by DURRIDGE COMPANNY Inc. From each village four water samples were taken and analyzed for radon concentration. The water samples were collected from Tube well. The water samples were taken in 250-ml vials. In the present research, as a sample was collected, it was analyzed immediately on the entire sampling site. The time difference between taking the sample and analyzing it was few minutes, so no decay of radon in the water occurred.

The RAD7 H_2O is an accessory to RAD7 that enables measurement of radon in water over a concentration range from < 10 pCi/l to > 4 x 10^5 pCi/l. The equipment is portable and battery operated, and the measurement is fast. Figure 2 shows the schematic diagram of RAD7 H_2O. The operation of this instrument is based on the following principle: (i) radon is expelled from water sample by using a bubbling kit, (ii) expelled radon enters a hemisphere chamber by air circulation, (iii) polonium decayed from radon is collected onto a silicon solid state detector by an electric field, (iv) radon concentration is estimated from the count rate of polonium. RAD H_2O gives results after a 30 min analysis with a sensitivity that matches or exceeds that of liquid scintillation methods. The RAD H_2O method employs a closed loop aeration scheme whereby the air volume and water volume are constant and independent of the flow rate. The air recirculates through the water and continuously extracts the radon until a state of equilibrium develops. The RAD H_2O system reaches this state of equilibrium within about 5 min, after which no more radon can be extracted from the water. The extraction efficiency or percentage of radon removed from the water to the air loop is very high about 94% for a 250 ml sample. The exact value of the extraction efficiency depends somewhat on ambient temperature, but it is almost always well above 90%. The RAD7 detector converts alpha radiation directly to an electric signal. RAD7 has the ability to distinguish between old and new radon [14]. As per EPA recommendations that all continous radon monitors be calibrated at least every 6 months in a radon calibration chamber, the instrument was calibrated recently. The spectrum obtained from RAD7 at the end of a run was carefully observed and there were clearly defined peaks and no noise across the spectrum. The peaks were located in the middle of the windows, which indicate the perfect working order of the instrument and hence reliable and accurate readings.

RESULTS AND DISCUSSION

The results for radon concentration in drinking water samples collected from Hanumangarh and SriGanganagar districts of Northern Rajasthan are reported in Table 1. The values in samples from the Hanumangarh district were in the range 1.8 ± 0.7 Bq L^{-1} (Amar Singh wala) to 8.2 ± 1.1 Bq L^{-1} (Shahpini) with an average value of 3.70 Bq L^{-1}. In the SriGanganagar district these value were in the range from 2.0 ± 0.4 Bq L^{-1} (Gulabawala) to 7.3 ± 1.1 Bq L^{-1} (SriGanganagar city) with an average value of 4.05 Bq L^{-1}. The average radon activity concentration in water samples for the whole of the studied area is 3.87 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} [15]. 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} [16]. The recorded values of radon concentration in groundwater are within the safe limit of 11Bq L^{-1} recommended by the US Environmental Protection Agency [15]. The recorded values of radon concentration are within the recommended safe limit of 4-40 Bq L^{-1} [16]. 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 [17], all the recorded values were found to be well below the action level and hence safe for drinking purposes. The value of radon concentration obtained in groundwater was compared with those reported by other investigators. The radon concentration in water samples in Iran lies in the range 0.064-49.088 Bq l^{-1} [18]. Nikolopoulos and Louizi have reported radon concentration in water samples from Cyprus and Greece in the range 0.3-20.0 Bq l^{-1} and 0.8-24.0 Bq l^{-1}, respectively [19]. Marques et al. have reported a radon concentration range of 0.95-36.0 Bq l^{-1} in the Brazil [20]. Manzoor et al. have reported a radon concentration range of 2.0-7.9 Bq l^{-1} in water samples in the Pakistan [21]. The radon concentration in water samples in the Transylvania, Romania lies in the range 0.5-129.3 Bq l^{-1} [13]. Akar Tarim et al. have reported a radon concentration range of 1.46-53.64 Bq l^{-1} in water samples in the Bursa, Turkey [22]. The radon concentration in water samples in the Kenya lies in the range 0.8-371.7 Bq l^{-1} [23]. Cho et al. have reported a radon concentration range of 0-300.0 Bq l^{-1} in groundwater samples of Busan, South Korea [24]. Radon concentration values obtained in the groundwater samples in this investigation generally lies well within the range reported by other investigators as given in Table 2.

Table 1. Dissolved radon concentration in the 80 sampled tube well sources in Northern Rajasthan

Sr. No.	Sample Location	Radon Concentration in groundwater (BqL^{-1})				Depth (m)	Temp (^{o}C)
		Minimum	Maximum	Mean	SD		
District Hanumangarh							
1	Pilibanga	2.4	3.6	3.2	0.6	30.0	28.0
2	Hanumangarh city	2.2	3.2	2.7	0.5	36.0	28.9
3	Rawatsar	2.7	5.0	3.7	1.0	28.5	27.7
4	Morjand Sikhan	3.1	4.5	3.9	0.7	30.0	28.6
5	Shahpini	7.4	9.8	8.2	1.1	33.0	28.6
6	Nukera	2.1	4.7	3.5	1.1	28.5	32.5
7	Amar Singh wala	1.2	2.7	1.8	0.7	27.0	28.3
8	Sangaryia	2.6	4.2	3.1	0.8	33.0	28.0
9	Rasuwala	1.8	2.1	2.0	0.1	37.5	27.1
10	Amarpura jalukhatt	3.7	5.8	4.9	0.9	34.5	29.5
District SriGanganagar							
11	23Z	2.4	3.3	2.7	0.4	30.0	29.5
12	Gulabawala	1.7	2.6	2.0	0.4	27.0	29.2
13	3H	3.6	5.4	4.4	0.8	37.5	28.0
14	Malkana	2.3	4.7	3.5	1.0	27.0	29.2
15	Sangatpura	4.1	5.3	4.5	0.5	39.0	30.1
16	SriGanganagar city	6.3	8.5	7.3	1.1	30.0	30.1
17	Radewala	3.5	4.8	4.3	0.6	32.4	29.5
18	Karanpur	1.8	2.6	2.1	0.3	39.0	29.2
19	14Q	4.7	5.0	4.8	0.1	42.0	28.9
20	Kalian	3.2	6.7	4.9	1.4	27.0	29.5

Table 2. Comparison of radon concentration in groundwater with those reported by other investigators.

Region	Radon concentration in water (Bq l^{-1})		References
	Range	Mean value	
Iran	0.064-49.1	16.2	Binesh et al., 2010
Cyprus	0.3-20.0	5.9	Nikolopolus et al., 2008
Greece	0.8-24.0	5.4	Nikolopolus et al., 2008
Brazil	0.95-36	36.0	Marques et al., 2004
Pakistan	2.0-7.9	-----	Manzoor et al., 2008
Transylvania, Romania	0.5-129.3	15.4	Cosma et al., 2008
Bursa, Turkey	1.46-53.64	-----	Akar Tarim et al., 2012
Kenya	0.8-371.7	-----	Otwoma et al., 1998
Busan, South Korea	0-300.0	-----	Cho et al., 2004
Northern Rajasthan, India	1.8-8.2	3.87	Present investigation

Fig. 1 Map of Rajasthan showing the area surveyed during the study.

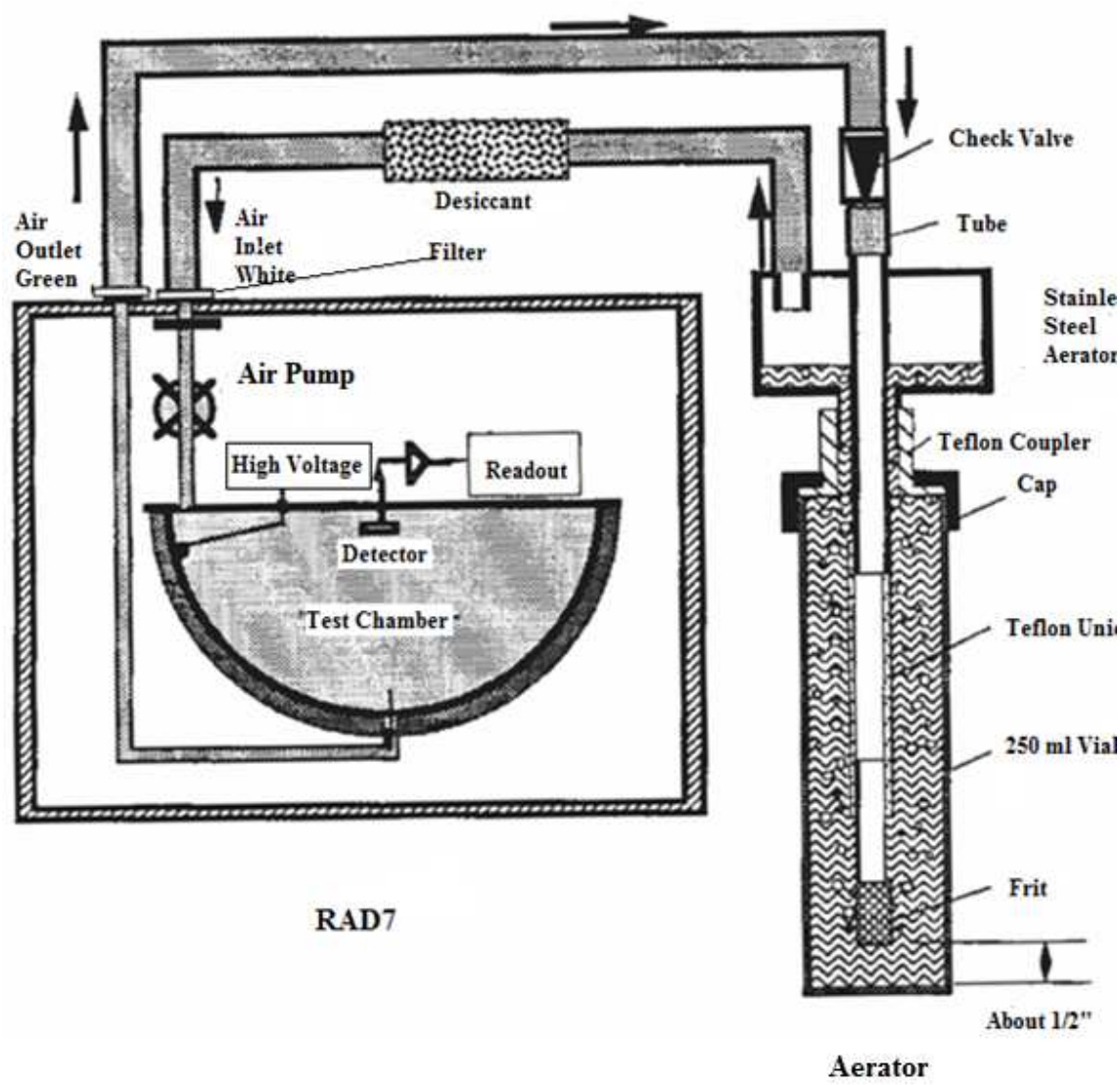

Fig. 2 Schematic diagram of RAD7 H_2O

CONCLUSION

The values in samples from the Hanumangarh district were in the range 1.8 ± 0.7 Bq L^{-1} (Amar Singh wala) to 8.2 ± 1.1 Bq L^{-1} (Shahpini) with an average value of 3.70 Bq L^{-1}. In the SriGanganagar district these value were in the range from 2.0 ± 0.4 Bq L^{-1} (Gulabawala) to 7.3 ± 1.1 Bq L^{-1} (SriGanganagar city) with an average value of 4.05 Bq L^{-1}. The average radon activity concentration in water samples for the whole of the studied area is 3.87 Bq L^{-1}. The recorded values of radon concentration in groundwater are within the safe limit recommended by the US Environmental Protection Agency [15] and United Nations Scientific Committee on the Effects of Atomic Radiation [16].

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