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Radon concentration in groundwater of Haridwar, Uttarakhand, India

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Abstract: Radon is produced during the radioactive decay chain of uranium and may be found under natural conditions anywhere in soil, air and in surface water and groundwater. For radiation protection and geological considerations, it is pertinent to carry out surveys for radon in natural water. The results presented in this paper are from the groundwater samples collected during a survey carried out in Haridwar area of Uttarakhand, India. Radon (²²²Rn) concentration was measured using DurrIDGE RAD-7. The ²²²Rn activity was measured in 6 representative groundwater samples and the values of ²²²Rn ranged between 2.64 ± 0.36 and 9.25 ± 0.85 Bq L⁻¹ with an average value of 6.24 ± 0.64 Bq L⁻¹, well within the EPA's maximum contaminant level of 11.1 Bq L⁻¹. Radon values were computed for correlation coefficient with other parameters viz. EC, pH and temperature and it was found that pH and temperature are moderately correlated and a modest correlation was found with EC. However, EC values ranged between 260 - 890 μ S/cm with an average value of 518 μ S/cm; pH values ranged between 7.3-7.9 with an average value of 7.6 and temperature values ranged between 18.5 - 23.7 °C with an average value of 20.7 °C.

Keywords: Radon concentration, Groundwater, Haridwar, Uttarakhand.

1. Introduction

Radiations (primordial, cosmic and artificial) constitute an important part of the environment. On relating to hygiene, it has been found that the human beings are vulnerable to more than half of the dose exposure from natural radiation sources [1,2] of the radon (²²²Rn) and its progeny. Radon is a naturally occurring, with a half-life of 3.82 days, odorless, colorless, tasteless inert gas found ubiquitously as ²²²Rn (radon), ²²⁰Rn (thoron) and ²¹⁹Rn (actinone) in soil, air & in surface water and groundwater in varying concentrations which is hardly noticeable to our sense. Radon is produced during the radioactive decay chain of uranium (²³⁸U) which contributes approximately 55% of internal radiation exposure to human life [3]. During decay of radon it is inhaled into the lungs where it releases energy and cause cancer by damaging the DNA in susceptible lung tissues. Groundwater can create a health risk by carrying additional radon into homes and other buildings as the dissolved radon is easily released into the air when the water is used for showering, cleaning, and other everyday purposes [4]. Cross et al (1985) [5] have reported that the levels of radon in indoor dwellings can be enhanced partially by radon derived from water supply [6] and exposure to high concentrations of radon for a long period lead to the respiratory functional changes and the occurrence of lung [7], stomach and gastrointestinal cancers [8]. 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 [9-16] and regarding its applications [17-19]. In Uttarakhand various studies had been carried out in river waters of Garhwal and Shivalik Himalayas and groundwater of the Doon valley where high radon concentrations have been reported [20, 21]. The present study is carried out in Haridwar area of Uttarakhand, India to investigate the radon levels in groundwater as it is widely used for drinking.

1.1. Study area

Haridwar district is located in south – western part of Uttarakhand State and it lies from 29° 35' to 30° 40' N latitude and 77° 43' to 78° 22' E longitude with the geographical area of the district is 2360 km². It falls under moderate sub-tropical to humid climate with average normal rainfall of 1174 mm and out of which more than 80% is recorded in the monsoon season. Major sources of drinking and irrigation are tube wells and rainfall is the only source of water for groundwater recharge.

1.1.1. Geology, hydro-geology and groundwater status of area

Geologically the area is divided into three zones viz. Shivaliks, 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 [22-24]. 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 report) [25]. 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 [25].

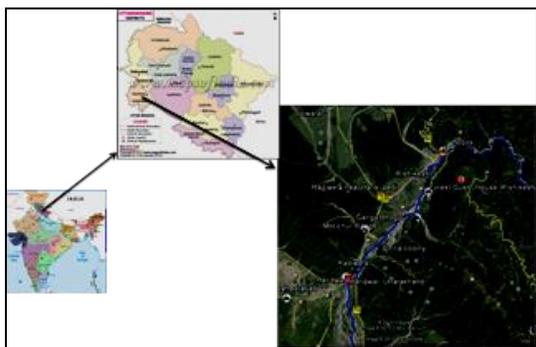


Figure 1 Study area

2. Methodology

A survey was conducted in the Haridwar area of Uttarakhand to collect 6 representative groundwater samples from the tube wells used for drinking and irrigation purposes and location along with coordinates details are shown in table 1 and figure 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. Radon concentrations in these samples were measured with RAD7, an electronic radon detector connected to a RAD-H₂O accessory (DurrIDGE Co., USA), within 12 hours of sample collection. Figure 2 shows the schematic diagram of the RAD H₂O. 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.

3. Results and Discussion

As evident from table 2, the values of ²²²Rn ranged between 2.64 ± 0.36 and 9.25 ± 0.85 Bq L⁻¹ with an average value of 6.24 ± 0.64 Bq L⁻¹, well within the EPA's maximum contaminant level of 11.1 Bq L⁻¹. Radon values were computed for correlation coefficient with other parameters viz. EC, pH and temperature and it was found that pH and temperature are moderately correlated and a modest correlation was found with EC (Table 3). However, EC values ranged between 260 – 890 μ S/cm with an average value of 518 μ S/cm; pH values ranged between 7.3-7.9 with an average value of 7.6 and temperature values ranged between 18.5 – 23.7°C with an average value of 20.7 °C (Table 1).

Table 1: Samples detail

Sample ID	Location	Longitude (E)	Latitude (N)
H-1	Radiwela, Haridwar	29°56'57"	78°10'08"
H-2	Forest Guest House, Rishikesh (Near Pashulok Beraje)	30°04'07"	78°17'06"
H-3	Vill Ganga Bhogpur	30°01'05"	78°15'52"
H-4	Chilla Colony (Near Chilla Power House), Haridwar	29°58'33"	78°12'34"
H-5	Radiwela, Haridwar (Near Harki Podi)	29°57'05"	78°10'17"
H-6	Bahadrabad	29°55'14"	78°02'23"

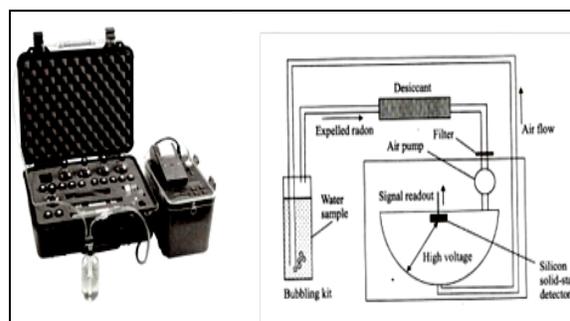


Figure 2 RAD7 connected with RAD7H₂O & accessories

Table 2: EC, pH, temperature & concentration of radon in groundwater samples

Sample ID	EC ($\mu\text{S/cm}$)	pH	Temp. ($^{\circ}\text{C}$)	Radon (BqL^{-1})
H-1	260	7.9	19.2	2.64 \pm 0.36
H-2	890	7.4	21.3	5.94 \pm 0.77
H-3	670	7.3	23.7	9.25 \pm 0.85
H-4	530	7.6	22.4	7.81 \pm 0.61
H-5	310	7.9	18.5	6.65 \pm 0.68
H-6	450	7.6	18.8	5.16 \pm 0.54
Average	518	7.6	20.7	6.24 \pm 0.24

Table 3: Correlation of concentration of radon v/s EC, pH, temperature (Dancey and Reidy's, 2004) [26]

Measured parameters/Correlation coefficient	EC ($\mu\text{S/cm}$)	pH	Temperature ($^{\circ}\text{C}$)
R^2	0.23	0.41	0.55

Variation in radon concentrations may be due to the geological structure of the area [4]. Akawwi (2014) [27] found a significant positive correlation between radon concentration and water temperature in the groundwater samples of Jordan valley which suggested radon concentration increases with temperature. In an another study carried out in the groundwater of Jalandhar area of Punjab by Bandhan et al. [4], no significant correlation was observed between radon concentration and acidity.

4. Conclusion

The values of natural radioactivity measured in groundwater in Haridwar area of Uttarakhand covered in the present survey is within the permissible limits prescribed by USEPA (1991) [28]. Variations in levels of radon concentrations in all the sites need to be investigated in detail. No significant correlation of radon values were found with other parameters viz. EC, pH & temperature and it was found that pH & temperature are moderately correlated and a modest correlation was found with EC. However, some of the factors, such as precipitation, geologic and hydrologic variables are important and must be investigated.

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