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Studies on Uranium And Radon Concentration In Bore Well Water of Kodagu District, India

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Abstract: A systematic study on natural radioactivity in bore well water samples of Kodagu district, India was carried out with the use of LED fluorimetric and radon emanometric techniques. Uranium concentration in the studied water samples varied from 0.013 to 0.083 Bq l^{-1} with an average of 0.046 Bq l^{-1}. Radon concentration in these samples varied from 6.38 to 30.69 Bq l^{-1} with an average of 13.49 Bq l^{-1}. The total dose due to U and ^{222}Rn concentration in these water samples varied from 33.93 to 158.46 µSvy^{-1} with an average of 69.97 µSvy^{-1}. The average annual effective dose due to U and ^{222}Rn concentrations in bore well water samples are below the limiting values recommended by EPA, WHO and AERB. Estimated concentrations of uranium and radon were within the recommended MCL by USEPA.

Keywords: LED fluorimeter, Radon emanometry, Ingestion dose.

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I. INTRODUCTION

Radioactivity is ubiquitous in nature. Natural uranium and its daughter products such as radium and radon are present in natural soil and water at different levels of concentrations [1]. Uranium and radon will contribute a significant component of the radiation exposure to the population. When ground water moves through soil and rocks, radioactive elements get dissolved due to leaching from minerals and transported with the water. Intake of radionuclides above the maximum contaminant level causes health effects and these radionuclides in the environment will contribute radiological risk to the population. Uranium is the heaviest trace element, has widespread occurrence in nature and decays into several short-lived and long-lived radioisotopes including radium and radon. The concentration of uranium generally varies from 0.5 to 5ppm in natural soil and rocks [2]. The average concentration of uranium in the earth crust is 0.0003%. Natural uranium is a mixture of three isotopes ^{238}U (99.29%), ^{235}U (0.72%) and ^{234}U (0.0054%) [2,3]. The study of uranium in ground water is essential for the hydro geochemical prospecting of uranium and for the assessment of health risks to the public due to consumption of water [4]. ^{222}Rn is a chemically inert, colourless, odourless and radioactive noble gas with a half-life of 3.82 days. It is a daughter product of ^{226}Ra in uranium decay series. Radon is readily soluble in water and its mole fraction solubility in water is 2.3×10^{-4} at 15°C and 0.00125 at 37°C and its solubility decreases with temperature and increases with pressure. Radon gas can dissolve in groundwater and released into the indoor air during household activities as bathing, dish and cloth washing. Exposure to waterborne radon may occur by ingestion and inhalation. When inhaled over prolonged periods it is capable of causing lung cancer [1, 5]. A study on dissolved radionuclides in gives the key aspect for evaluation and control of natural exposure [6,7]. Therefore, radiological monitoring of water quality is an important parameter of environmental studies.

II. STUDY AREA

Kodagu district is having an area of 4,102 km^2, is located in southern part of Karnataka state, India. The district has mountainous configuration and is part of the eastern and western slopes of the Western Ghats of India. Kodagu district has abundant forest and unique climatic conditions with an average annual rainfall of about 2600 mm. Soil types found in this region are reddish brown forest soil, yellowish grey to greyish sandy loam in some parts mixed soils were also observed. Cauvery is the main and the largest river of the district. Irrigation in the district is on a minor scale and it is mainly through dug wells, bore wells, tanks, ponds and canals [8,9].

The Kodagu district forms a part of hard rock topography consisting gneisses, granites, amphibolites and charnockites. In the eastern and southern parts of the district pegmatite veins and dolerite dykes are found. The elevated regions are covered by laterites and the lowlying and flat regions are covered by a thick mantle of fertile soil. The ground water occurs in weathered zones of granites and gneiss in phreatic conditions. At deeper level, ground water occurs in joints and fractures of granites and gneiss in semi-confined to confined conditions [8,9]. The study area is shown in the figure 1.

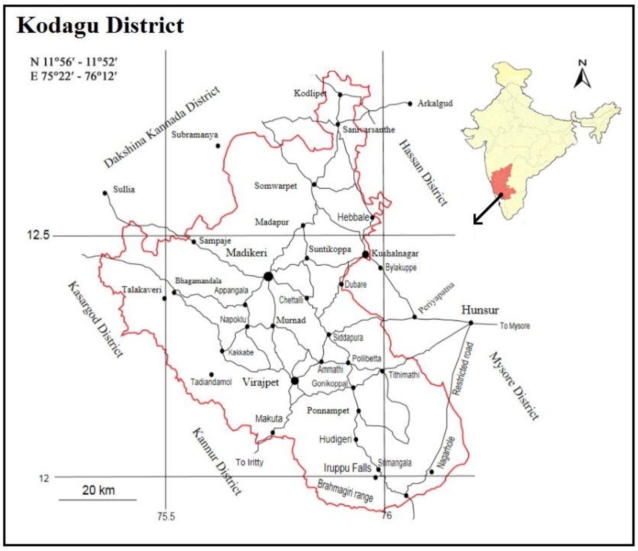

Figure 1: Study area

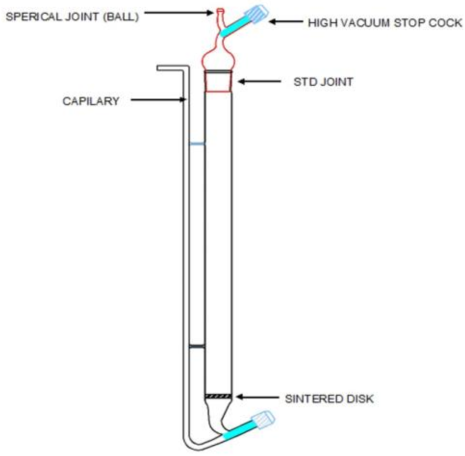

Fig 2. Schematic diagram of radon bubbler.

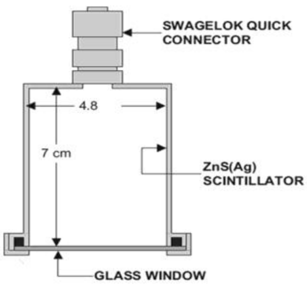

Fig 3. Schematic diagram of scintillation cell.

III. MATERIALS AND METHODS

3.1 Estimation of Radon concentration in water:

The activity concentration of ^{222}Rn in water was estimated by the radon emanometry technique. The water samples were collected from each location of the study area in airtight bottles of 250 ml capacity. The samples were brought to the laboratory with minimum disturbance and about 70 ml of the water sample was transferred into the radon bubbler (Fig. 2). The dissolved radon gas in the water sample is transferred from bubbler into a pre evacuated scintillation cell. The scintillation cell is a cylindrical vessel of 150 cc volume fitted with a swagelok connector on one side for evacuation and sampling and on the other side a glass window optically coupled to a photo multiplier assembly (Fig 3). The inner walls of the cell is coated with ZnS(Ag) which produces light scintillations due to alpha particles emitted by radon and its progeny. The radon dissolved in water was transferred into the pre-evacuated scintillation cell using radon bubbler. A time delay of 180 minutes was given before counting the scintillation cell for alpha activity to allow radon to reach equilibrium with its daughters. The concentration of radon in water was calculated using the relation given by Raghavayya [10,11].

$$^{222}Rn\left(BqL^{-1}\right)=\frac{6.97\times10^{-2}\times(D\pm SD)}{V\times E\times\left(e^{-\lambda T}\right)\times\left(1-e^{-\lambda t}\right)}$$

Where,
D = Counts above background (s^{-1})
SD = Standard deviation
V = Volume of water (70 ml)
E = Efficiency of the scintillation cell (74 %)
λ = Decay constant for radon (2.098 x 10^{-6} s^{-1})
T = Counting delay after sampling
t = Counting period (s)

3.2 Ingestion dose and inhalation dose due to ^{222}Rn in water

$$D_{In}(\mu Svy^{-1})=C_R\times R_{aW}\times I\times DCF$$

Where D_{In} is the effective dose for inhalation, C_R is the Rn concentration in water (kBq/m^3) , R_{aW} is the ration of Rn in air to Rn in water (10^{-4}), F is the equilibrium factor between Rn and its progenies (0.4), I is the average indoor occupancy time for an individual (7000h y^{-1}) and DCF is the dose conversion factor for Rn exposure (9nSv (Bqhm^{-3})).

$$D_{Ig}(\mu Sv\,y^{-1})=C_R\times C_W\times EDC$$

Where D_{Ig} is the effective dose for ingestion, C_R is the ^{222}Rn concentration in water (kBq/m^3), C_W is the weighed estimate of water consumption (730 l y^{-1}) and EDC is the Effective Dose Coefficient for ingestion (3.5 nSv/Bq) respectively [1].

3.3 Uranium concentration in water using LED Fluorimeter

The concentration of uranyl salt in water samples were measured using a compact, portable LED Fluorimeter. LED fluorimeter is an analytical instrument used to measure uranium concentration in water samples. It is one of the most sensitive, accurate and precise method capable of measuring uranium concentrations down to 0.2 ppb [12]. In LED Fluorimeter works on the principle of detection of fluorescence of uranyl complex formed by the addition of an inorganic reagent called fluran [13, 14]. The instrument was regularly calibrated using a standard stock solution of 1.179 g of U_3O_8 which was diluted to specific concentrations. The fluorescence-enhancement was done using sodium pyrophosphate (5 %). A 5 ml of water sample was placed in a dry and clean cell, 1 ml of 5 % sodium pyrophosphate (pH 7) was added and fluorescence counts were noted. The concentration of uranium (ppb) in samples was calculated using the following equation:

$$U(ppb)=\frac{D_1}{D_2-D_1}\left(\frac{V_1C}{V_2}\right)$$

Where
D_1 is the fluorescence counts due to sample only
D_2 the fluorescence counts due to sample and uranium standard
V_1 the volume of uranium standard added (ml)
V_2 the volume of sample taken (ml) and
C is the concentration of uranium standard solution (ppb).

3.3 Ingestion dose due to Uranium in drinking water:

Ingestion dose can be estimated using the intake of uranium through drinking water pathway for different age groups according to the water intake rates. According to the ICRP-60, dose coefficients for infants is 1.2×10^{-7}, 6.8×10^{-8} for children and 4.5×10^{-8} $SvBq^{-1}$ for male and female adults [15]. Total effective radiation dose was calculated considering drinking of 730 ly^{-1}. This corresponds to 2 liter of water consumed daily by the people. Dose conversion factor (DCF) is equal to 4.5×10^{-8} $SvBq^{-1}$ for ^{238}U. The annual radiation ingestion dose due to uranium intake through the drinking water pathway was calculated using the following equation:

Ingestion dose (Sv.y^{-1}) = Uranium concentration (Bq .l^{-1}) x Intake of water (l.y^{-1}) x DCF (Sv Bq^{-1}).

IV. RESULTS AND DISCUSSION

Uranium and ^{222}Rn concentrations were measured in water samples collected from bore wells in the Kodagu district and the results are given in table 1. Uranium concentration in the studied water samples varies from 0.013 to 0.083 Bq l^{-1} with an average of 0.046 Bq l^{-1}. ^{222}Rn concentration varies from 6.38 to 30.69 Bq l^{-1} with an average of 13.49 Bq l^{-1}. The total dose due to U and ^{222}Rn concentration in water varies from 33.93 to 158.46 μSvy^{-1} with an average of 69.97 μSvy^{-1}. The average annual effective dose due to U and ^{222}Rn concentrations in bore well water samples are below the MCL limit recommended by EPA, WHO and AERB. The annual effective dose is well below the recommended limit of 100 μSvy^{-1} [16-18].

Maximum Uranium concentration in ground water is observed at Chettalli village of Somavarapet Taluk. Higher concentration of uranium in this region may be due to presence of granite rocks present in this region. Uranium easily dissolves in water and occurs both in dissolved and particulate forms. It can enter food chain from soil, water and fertilizers. The concentration of uranium in water varies from one place to the other depending on type of soil, rocks, lithology, geomorphology and other geological conditions. Even though the most parts of the study area contains different types of gneisses and granite rocks the uranium concentration in water sample on the uranium content in the host aquifer rock [1,6,7]. The variation between radon concentration and uranium concentration in water is shown in figure 4. A poor correlation has been observed between radon concentration and uranium concentration in water.

V. CONCLUSION

A study on dissolved radionuclides in borewell waters of Kodagu district has been reported. Uranium concentration in the studied water samples varies from 0.013 to 0.083 Bq l^{-1} with an average of 0.046 Bq l^{-1}. Radon concentration varies from 6.38 to 30.69 Bq l^{-1} with an average of 13.49 Bq l^{-1}. The total dose due to U and ^{222}Rn concentration in water varies from 33.93 to 158.46 μSvy^{-1} with an average of 69.97 μSvy^{-1}. The average annual effective dose due to ^{238}U and ^{222}Rn concentrations in bore well water samples are below the MCL limit recommended by EPA, WHO and AERB. The annual effective dose is well below the recommended limit of 100 μSvy^{-1}.

Table 1: Uranium and Radon concentration in borewell water of Kodagu district.

No.	**Locations**	**No. of samples**	**Uranium conc. (Bql^{-1})**	**Radon conc. (Bql^{-1})**	**Ingestion dose due to Uranium (μSvy^{-1})**	**Ingestion dose due to Radon (μSvy^{-1})**	**Inhalation dose due to Radon (μSvy^{-1})**	**Total dose (μSvy^{-1})**
1	Kodlipet	5	0.048	6.38	1.58	16.29	16.07	33.93
2	Sampaje	4	0.055	7.37	1.81	18.82	18.56	39.18
3	Ponnampet	4	0.020	9.13	0.66	23.31	23.00	46.97
4	Sanivarasanthe	6	0.041	10.35	1.33	26.43	26.07	53.84
5	Somavarapet	4	0.062	10.52	2.04	26.88	26.52	55.44
6	Madapur	4	0.036	12.60	1.18	32.19	31.75	65.13
7	Virajpet	3	0.013	13.11	0.44	33.49	33.03	66.96
8	Napoklu	4	0.032	14.10	1.05	36.02	35.52	72.59
9	Madikeri	5	0.069	14.53	2.27	37.11	36.60	75.98
10	Suntikoppa	5	0.046	15.18	1.51	38.77	38.24	78.52
11	Siddapura	6	0.045	17.96	1.48	45.88	45.25	92.62
12	Chettalli	4	0.083	30.69	2.73	78.40	77.33	158.46
	Minimum		0.013	6.38	0.44	16.29	16.07	33.93
	Maximum		0.083	30.69	2.73	78.40	77.33	158.46
	Average		0.046	13.49	1.51	34.47	34.00	69.97
	G.M		0.041	12.40	1.36	31.68	31.24	64.48
	S.D.		0.020	6.37	0.65	16.28	16.06	32.67

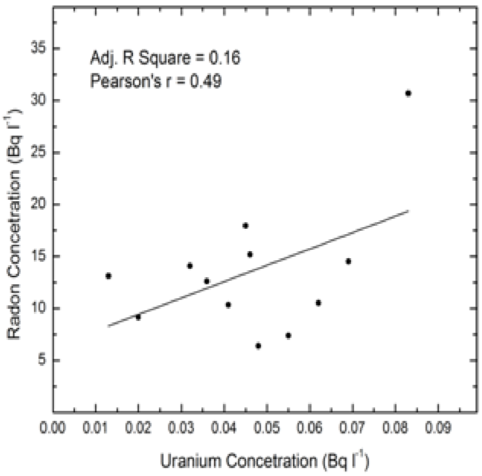

Fig 4: Correlation between Radon concentration and Uranium concentration in water.

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