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Radon Concentration in the Water Samples of Hassan District, Karnataka, India

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Abstract**—**Radon is a radioactive gas emitted from radium, a daughter product of uranium that occurs naturally in rocks and soil. Radon, together with its decay products, emits alpha particles that can damage lung tissue. The activity concentration of ^{222}Ra has been analyzed in water samples collected from borewells and rivers in and around Hassan city, Karnataka State, India. The measurements were performed by Emanometry technique. The concentration of ^{222}Rn in borewell waters varies from 18.49±1.89 to 397.26±12.3 Bql^{-1} with geometric mean 120.48±12.87 Bql^{-1} and in river waters it varies from 92.63±9.31 to 93.98±9.51 Bql^{-1} with geometric mean of 93.16±9.33 Bql^{-1}. In the present study, the radon concentrations are higher in Adarshanagar and Viveka Nagar which are found to be 397.26±12.3 Bql^{-1} and 325.78±32.56 Bql^{-1}. Most of the analysed samples show a ^{222}Rn concentration more than 100 Bql^{-1} and this can be attributed to the geology of the area where the ground waters are located, which is predominantly of granitic characteristic. The average inhalation dose and ingestion dose in the borewell water are found to be 0.405 and 0.033 µSvy^{-1}; and in river water it is found to be 0.234 and 0.019 µSvy^{-1}, respectively. The average total effective dose rate in borewell waters and river waters are found to be 0.433 and 0.253 µSvy^{-1}, which does not cause any health risk to the population of Hassan region.

Keywords**—**Borewell, effective dose, emanometry, ^{222}Rn.

I. Introduction

RADON (Rn) is a naturally occurring, colourless, odourless gaseous element that is soluble in water. The ^{222}Rn proportion in groundwater depends on the presence of ^{226}Ra, its parent in the ^{238}U radioactive decay series with which it comes into radioactive equilibrium in about 25.6 days [1]. Radon existing in rocks of the earth's terrestrial systems diffuses continuously through water in rocks, which leads the presence of radon in ground water [2]. Drinking water is usually provided by groundwater or surface water sources. Different substances present in the water source, such as radioactive elements, can dissolve in water and contaminate drinking water resources [3]. The energetic alpha particles emitted from ^{222}Rn and two of its daughter elements, viz. ^{214}Po and ^{218}Po, are highly effective in damaging the tissue and are considered to be causative agent for lung cancer in human being [4].

The natural radionuclide's presence in groundwater can vary in several orders of magnitude and is influenced by physical (temperature), chemical (pH) and geological properties of the aquifer [5]-[8]. According to USNRC, radon is a noble gas has highest solubility in water, with the mole fraction value (1.25 x 10^{-5} at 37 ^{0}C) of fifteen times higher than that of neon and helium [9]. In addition, Environmental Protection Agency (EPA) estimates that radon in drinking water causes about 168 cancer deaths per year: 89% from lung cancers caused by breathing radon released to the indoor air from water and 11% from stomach cancer caused by consuming water containing radon [10].

Regarding the radon concentration in water, the limits proposed by the Environmental Protection Agency are of 11.1 Bql^{-1} for ^{222}Rn in drinking water [11]. This limit is related to the probable indoor contribution of water to the environment. Interestingly, the recommendation of the European Commission [12] is 100 Bql^{-1}, with the limit for intervention at 1000 Bql^{-1}, whereas the radon contained in this water is both ingested and inhaled, and total effective dose rate should not exceed 0.1 mSvy^{-1} associated with the water consumption by human population [13].

The area of present study is Hassan district (12° 30' and 13° 35' N latitude and 75° 15' and 76° 40' East longitude) which is located on the border of the Western Ghats, in the southern part of Karnataka state as shown in Fig. 1. The major part of the district is in the Cauvery main basin drained by Cauvery, Hemavathy and Yagachi rivers, which flow towards east to join the Bay of Bengal. The groundwater quality is good and safe enough for drinking and agriculture purposes in Hassan region [14].

II. Geology of the Area

The soils of the Hassan district are red soil, red sandy soil, mixed soil, and silty clay soil generally derived from the crystalline rock and these soils have thin layers and are less fertile. The soils in the western and eastern taluks are red sandy type due to the presences of granite, gneisses and schists. Migmatization of pre-existing metasedimentary and meta–igneous rocks are considered as the contributors to formation of the composite gneiss [14]-[16].

These are a rich, friable soil containing a relatively equal mixture of sand and silt and a somewhat smaller proportion of clay and are intermixed with coarse gravel, pebbles and they are well drained but poor in moisture retaining capacity. Weathered and fractured gneiss, granite and schist are the major water bearing formations. Alluvial formation of the limited thickness and aerial extent is found along the courses of major rivers. Groundwater occurs under the phreatic (water table) conditions in weathered zones of gneiss, schist and granite and under semi-confined to confined conditions in

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joints and fractures of these rocks at deeper levels [14]-[16].

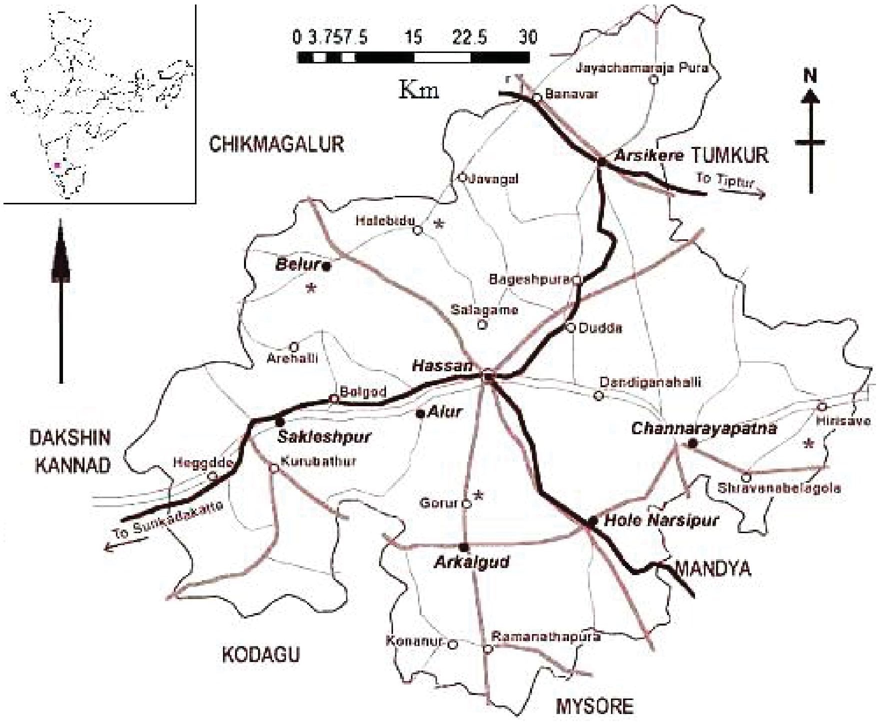

Fig. 1 Geology Map of Study area

III. Materials and Methods

The water samples were collected from in and around Hassan City. About 100 mL of borewell water samples and river water samples were collected in airtight plastic bottles with minimum disturbance. The bottles were completely filled so that zero headspace was present, and no air bubbles were present inside the container and also to avoid aeration during the sampling process, which might lead to out gassing [17]. During the sample collection, we have to follow the following procedure. Escape of radon from water due to turbulent flow is minimized by running a hose from the wellhead faucet into a bottle. Bottles are filled and capped underwater without any airspace left in the sample. The samples were analyzed for ^{222}Rn in water immediately with the minimal loss of time by Emanometry method [18], [19] as shown in Fig. 2. In the present work, water samples were transferred into the bubbler by the vacuum transfer technique and the dissolved radon in the water was transferred into a pre–evacuated and background counted scintillation cell [20] as shown in Fig. 3. The scintillation cell was kept for 3 hours or more to allow radon daughters to reach equilibrium with radon. Then, it was coupled to photomultiplier and alpha counted for a period of 1000 s [21]. The ^{222}Rn concentrations in water samples were determined by using (1), [22]:

$$^{222}Rn\left(BqL^{-1}\right)=\frac{6.97*10^{-2}*D}{V*E*\left(e^{-\lambda T}\right)*\left(e^{-\lambda\theta}\right)*\left(1-e^{-\lambda t}\right)} \quad (1)$$

where, D = counts above background, V = Volume of water, 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 duration (s), θ = build up time in the bubbler (s).

IV. Dose due to Dissolved ^{222}Rn in Water

By using the measured ^{222}Rn concentration of borewell water samples and river water samples, the effective dose for the population of the region was estimated, and the results are shown in Tables I and II. The effective dose to the ingestion mainly depends upon the amount of water consumed by a human being in a day [23]. The parameters for the inhalation pathway were ^{222}Rn concentration in water, air water concentration ratio of 10^{-4}, indoor occupancy of 7000 hours per year, and inhalation dose coefficient applied for the gas. The doses due to inhalation and ingestion are calculated by using (2) and (3), [24]:

$$Inhalation(\mu Sv):^{222}Rn.conc.\left(Bql^{-1}\right)\times10^{-4}\times7000h\times0.4\times9nSv\left(Bqhm^{-3}\right)^{-1} \quad (2)$$

$$Ingestion(\mu Sv):^{222}Rn.conc.\left(Bql^{-1}\right)\times60Ly^{-1}\times10^{-3}m^{3}l^{-1}\times3.5nSvBq^{-1} \quad (3)$$

V. Results

The radon concentrations in borewell waters and river waters were measured in and around Hassan districts by using Emanometry method and the doses due to dissolved radon are shown in Tables I and II. The variation of radon concentration in borewell waters collected from different locations is shown in Fig. 4, and radon concentrations in ground waters and river waters are shown in Fig. 5.

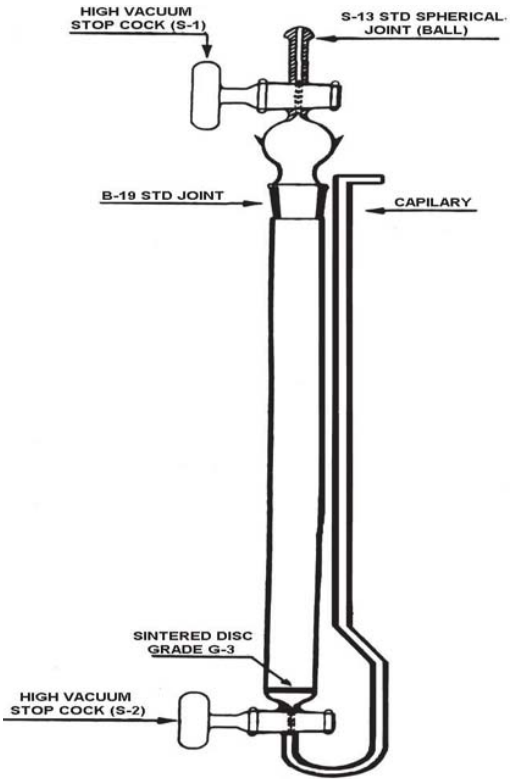

Fig. 2 Radon Bubbler

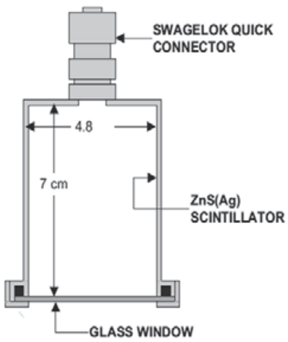

Fig. 3 Scintillation cell

The ^{222}Rn concentration in borewell water varies from 18.49±1.89 to 397.26±12.3 Bql^{-1} with a geometric mean of 120.48±12.87 Bql^{-1}. The higher radon concentration in borewell water was observed near Adarshnagar and Vivekanagar with an average value of 397.26±12.3 and 325.78±32.56 Bql^{-1}. Most of the analysed samples show ^{222}Rn activity more than 100 Bql^{-1} (EPA) and it is due to the geology of the area where the ground waters are located, which predominantly indicates the presence of their parents, ^{238}U and ^{226}Ra in the water-rock system. Groundwater is the water contained beneath the surface in rocks and soil, and is the water that accumulates in underground aquifers. Ground water occurs under phreatic condition in weathered zone of gneiss, granites, pegmatite, metamorphic rocks, and schist which contain higher activity of radionuclides to the confined conditions in joints and fractures of these formations at deeper level [12]. Higher porosity might allow the radon gas to escape easily while the lower porosity of the soil and intact rocks above the aquifer reduces the probability of gas escape and contribute to increase ^{222}Rn levels in groundwater [25].

^{222}Rn concentration in river water varies from 92.63±9.31 to 93.98±9.51 Bql^{-1} with geometric mean of 93.16±9.33 Bql^{-1}. Radon concentration in river water is observed to be within the limit of Environmental Protection Agency due to the lack of major contact with radon emanating mineral material and also on the natural tendency of radon to diffuse out of water into the air. The concentrations of radon in water may range over several orders of magnitude, generally being highest in well water, intermediate in ground water, and lowest in surface water [26] and from Fig. 5, we can see that the radon concentrations in ground waters are higher when compared with the river waters of Hassan district.

In Table III, we can see a summary of the information gathered by other researchers in different parts of the world on groundwater. However, we cannot find a direct relation between lithology and ^{222}Rn because there are numerous factors which influence the mobility of the different nuclides in water.

The average inhalation and ingestion dose in borewell waters are found to be 0.405 and 0.03 µSvy^{-1} and in river waters it found to be 0.234 and 0.019 µSvy^{-1}. The average total effective dose is also calculated in borewell and river waters which are found to be 0.433 and 0.253 µSvy^{-1}. The results are below the prescribed dose limit of 100 µSvy^{-1} recommended by World Health Organisation and European council.

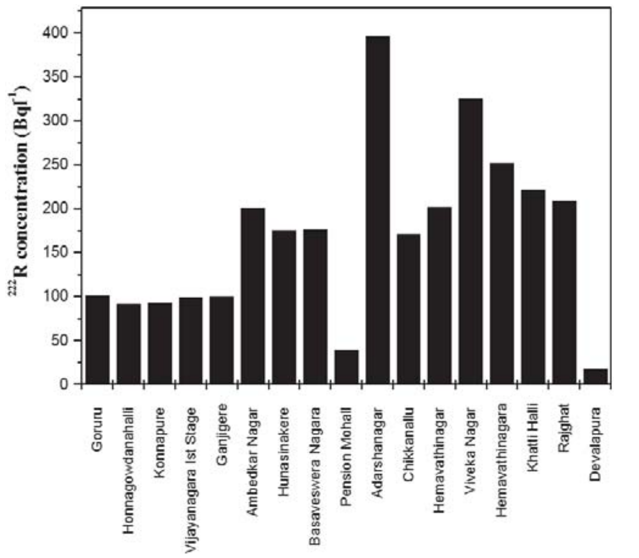

Fig. 4 Variation of radon concentration in borewell waters collected from different locations of Hassan district

TABLE I
^{222}RN CONCENTRATION IN BOREWELL WATER SAMPLES AND THEIR ANNUAL EFFECTIVE DOSE FROM DIFFERENT LOCATIONS OF HASSAN DISTRICT

Locations	222Rn conc. (Bql-1)	Inhalation Dose (μSvy^{-1})	Ingestion Dose (μSvy^{-1})	Total Dose (μSvy^{-1})
Goruru	101.47±10.5	0.255	0.021	0.276
Honnagowdana halli	92.63±8.63	0.233	0.019	0.252
Konnapura	93.98±8.91	0.236	0.019	0.255
Vijayanagara Ist stage	99.69±9.16	0.251	0.020	0.271
Ganjigere	101.27±11.5	0.255	0.021	0.276
Ambedkar Nagar	201.87±21.2	0.508	0.042	0.55
Hunasinakere	176.51±18.1	0.444	0.037	0.481
Basaveswera nagara	176.84±18.3	0.445	0.037	0.482
Pension mohalla	40.16±4.12	0.101	0.008	0.109
Adarshanagar	397.26±12.3	1.001	0.083	1.084
Chikkanallu	171.69±17.2	0.432	0.036	0.468
Hemavathi nagar	202.15±21.0	0.509	0.042	0.551
Vivekanagar	325.78±32.56	0.820	0.068	0.888
Hemavathinagara	252.11±25.2	0.635	0.052	0.687
Khatti halli	222.20±21.56	0.559	0.046	0.605
Rajghat	210.01±20.19	0.529	0.044	0.573
Devalapura	18.49±1.89	0.046	0.003	0.049
Min	18.49±1.89	0.046	0.003	0.049
Max	397.26±12.3	1.001	0.083	1.084
Average	160.95±15.43	0.405	0.033	0.433
Geometric mean	120.48±12.87	0.303	0.025	0.328

TABLE II
222RN CONCENTRATION IN RIVER WATER SAMPLES AND THEIR ANNUAL EFFECTIVE DOSE FROM DIFFERENT LOCATIONS OF HASSAN DISTRICT

Locations	^{222}Rn conc. (Bql^{-1})	Inhalation Dose (μSvy^{-1})	Ingestion Dose (μSvy^{-1})	Total Dose (μSvy^{-1})
Konnapura	93.98±9.51	0.236	0.019	0.255
Goruru Dam	92.90±9.20	0.234	0.019	0.253
Hemavathi	92.63±9.31	0.233	0.019	0.252
Min	92.63±9.31	0.233	0.019	0.252
Max	93.98±9.51	0.236	0.019	0.255
Average	93.17±9.51	0.234	0.019	0.253
Geometric mean	93.16±9.33	0.234	0.019	0.253

TABLE III
^{222}RN CONCENTRATION IN GROUND WATER SAMPLES AT DIFFERENT PARTS OF THE WORLD

Region	^{222}Rn (Bq/l)	References
Coonoor Tamilnadu	0.03-5.72	[27]
Coastal Kerala	0.3-1.31 (0.29)	[28]
Israel	61-274	[29]
Korea	50 -300	[30]
Brazil	<1.2 -3542 (57.7)	[31]
Finland	27-460	[32]
China	0.71- 735 (229.4)	[33]
South America	14.64	[34]
SW Poland	0.2-1645(240)	[35]
Bangalore	5.3-283(87.0)	[36]
Rajasthan	1.6-5.4 (3.3)	[37]
Mysore	BDL-643.9	[38]
Hassan	18.49-397.26	[Present work]

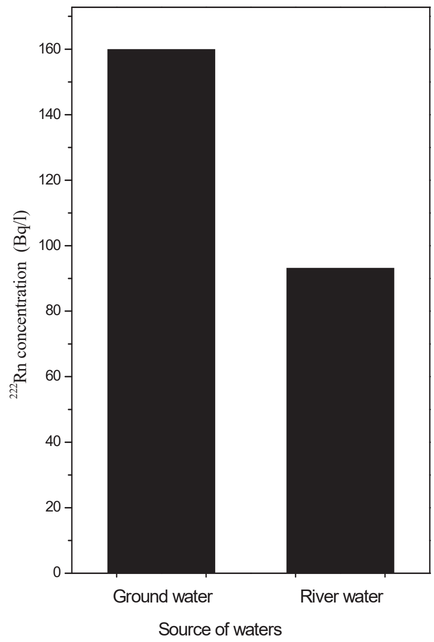

Fig. 5 Radon concentration in ground waters and river waters

VI. CONCLUSION

The ^{222}Rn concentration in borewell waters and river waters were measured in and around Hassan districts by using Emanometry method. The average concentration of ^{222}Rn in borewell waters and river waters are found to be 160.95±15.43 and 93.17±9.51 Bql^{-1}. Most of the analysed samples show ^{222}Rn activity more than 100 Bql^{-1} due to the geology of the area, which contain higher activity of radionuclides. The average inhalation, ingestion, and total effective dose are below the prescribed dose limit of 100 μSvy^{-1} recommended by World Health Organisation. So, the consumption of these waters does not cause any health risk to the population of Hassan region.

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