Original Article

Studies on radon concentration in aqueous samples at Mysore city, India

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Abstract

Context: Natural radionuclides are wide spread in air, water, soil, plants and in consequence in the human diet. ^{222}Ra is the daughter product of ^{226}Ra which belongs to ^{238}U radioactive series. **Aims:** Radon enters the human body through ingestion of water and inhalation. Since alpha emitters are the most dangerous, studies on water containing dissolved radon are very important. **Materials and Methods:** The activity concentration of ^{222}Ra has been analyzed in water samples collected from lakes, open wells, drilled wells, taps and rivers in and around Mysore city, Karnataka State, India using radon emanometric technique. **Results:** The present study shows a wide range of radon concentration in water, which varies from below detection limit to 643.9 BqL^{-1} with a median of 15.8 BqL^{-1}. An annual effective dose with a median of 0.043 μSv y^{-1} was estimated from the ingestion of ^{222}Ra through water. **Conclusions:** ^{222}Rn concentration in 80% of bore-well water samples are higher than the maximum acceptable contaminant level of 11.1 BqL^{-1} as prescribed by the environmental protection agency.

Keywords: Effective dose, emanometry, Mysore, ^{222}Ra, water

INTRODUCTION

^{222}Ra is a chemically inert, colorless, odorless and radioactive noble gas with a half-life of 3.82 days. Radon is soluble in water and its mole fraction solubility is 2.3×10^{-4} at 15°C and 1.25×10^{-4} at 37°C. The solubility coefficient of radon in water is 0.254 at 20°C and its solubility decreases with an increase in temperature and increases with an increase in pressure.[1] This property allows a high concentration of radon in ground water. Emanation of radon in the soil and water depends on the meteorological conditions like temperature, pressure and wind velocity.[2] Radon concentration is high in groundwater, which is extracted from drill holes and springs flowing through crystalline rocks or uranium rich bedrock. Radon gas can dissolve in groundwater and later be released into the air during normal household activities such as showering, dishwashing and doing laundry.[3,4] When radon accumulates in indoor air, it can pose an increased health risk. It is a major contributor to the ionizing radiation dose received by the general population. Exposure to waterborne radon may occur by ingestion and inhalation. When inhaled over prolonged periods of time they are capable of causing lung cancer.[5] A study on dissolved radionuclides in aquatic environment gives the key aspect for evaluation and control of exposure to the natural radionuclides.

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STUDY AREA

The study area is Mysore city, Karnataka, India which lies between 12°13″-12°25″ N latitude and 76°27″- 76°45″ E longitude, at an altitude of about 767 m amsl [Figure 1] forming a part of the catchment zone of the Cauvery and Kabini rivers. Mysore city has an area of about 89 sq km. A large water reservoir namely Krishnaraja Sagar (KRS) is situated towards northwest of Mysore city and Chamundi hill (1048 m amsl) is situated towards south east of Mysore. The archean rocks of South India are best developed in Mysore region and are made up of schists, gnesis, pegmatites and granites. The soil in Mysore region is red, sandy and loamy in the entire district. Pegmatitic intrusions into the precambrian gneisses and

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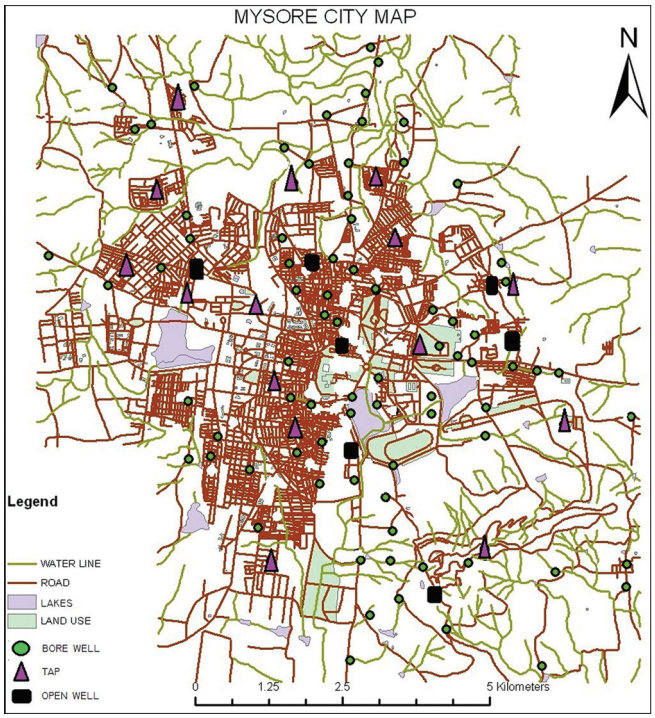

Figure 1: Study area

schists have also been found in several areas. The study area consists of a common water-divide zone caused by two rivers, the Cauvery and the Kabini. The thickness of the weathered zone varies between 3 m and 5 m over much of the Mysore region.[6,7] The drinking water source for most of western and northern part of the city is from the KRS dam through tap water after proper water treatment and large part of the Southern and Eastern region of the city from the Kabini river. Bore well water is supplied through the tap for the region where the river water is not supplied. In some seasons, large part of the city gets the water supply from the drilled bore wells through the tap.

MATERIALS AND METHODS

Estimation of ^{222}Rn activity by emanometry method

About 100 water samples were collected from bore wells, lakes, open wells, tap and rivers at different locations in and around Mysore City. Samples are collected from all the working bore wells and tap waters in such a way that, a minimum of 10 samples are collected in each square kilometre of the study area. Samples are collected from public and few private open wells and in all the lakes in and around the Mysore city. River water samples are collected from KRS (Cauvery river) and Kabini river.

The ^{222}Rn activity concentration in water samples was estimated by the radon emanometry.[8] Water samples were collected in airtight plastic bottles in a gentle manner to prevent the formation of air bubbles inside the container and also to control the aeration during the water sampling process. The samples were brought to the laboratory with minimal loss of time and were analyzed immediately. In this method, about 70 mL of the water sample was transferred into the 100 mL volume bubbler by the vacuum transfer technique. The scintillation cell was connected to a radon bubbler through rubber tubing, then agitating the water in the bubbler, the dissolved radon gets released and enters into a pre-evacuated and background counted ZnS (Ag) scintillation cell of volume 150 cc. The scintillation cell with collected radon gas was stored for 180 min to allow radon to attain equilibrium with its daughters and then it was coupled to a photomultiplier and programmable alpha counting system. Alpha probe comprises a ZnS (Ag) scintillator, detector coupled to a photomultiplier tube. The instrument is calibrated for the qualitative analysis of low level radon in aqueous samples, hence the calibration is performed using a standard alpha source Am-241 of strength 4260 dpm. The lower detection limit of the instrument is 0.05 BqL^{-1}. Replicate measurements were done to confirm the experimental values and the concentration was calculated using the following equation (1)[8]

$$^{222}\mathrm{Rn\,(BqL^{-1})} = \frac{6.97\times10^{-2}\times\mathrm{D}}{\mathrm{V}\times\mathrm{E}\times(\mathrm{e}^{-\lambda\mathrm{T}})\times(1-\mathrm{e}^{-\lambda\mathrm{t}})} \quad (1)$$

Where, D is difference between background counts and sample counts, V is volume of water (70 mL), E is efficiency of the scintillation cell (74%), λ is decay constant for radon (2.098 × 10^{-6} s^{-1}), T is counting delay after sampling (s), t is counting duration in (s).

Dose due to ^{222}Rn concentration in water

The effective dose for an adult who drinks 60 Ly^{-1} of water was estimated using the sum of dose due to ingestion and inhalation from the concentration of ^{222}Rn in the water samples.[9] The parameters for the inhalation dose were ^{222}Rn concentration in water, air water concentration ratio of 10^{-4}, indoor occupancy of 7,000 hy^{-1} and inhalation dose coefficient. The ingestion dose was estimated from the consumption of water by children and adults as 75 Ly^{-1} and 50 Ly^{-1} with dose coefficients of 5.9 nSvBq^{-1} and 3.5 nSvBq^{-1} respectively (International Commision on Radiological Protection ICRP 72).[10] Assuming the proportion of these groups in the population to be 0.3, and 0.65, the weighted estimate of consumption is about 60 Ly^{-1}. The dose due to inhalation and ingestion are calculated by the following equation (2 and 3).

$$\text{Inhalation (μSv)} = {}^{222}\text{Rn conc.(BqL}^{-1}\text{)} \times 10^{-4} \times 7{,}000\ \text{h} \times 0.4 \times 9\ \text{n Sv (Bq h m}^{-3}\text{)}^{-1} \quad (2)$$

$$\text{Ingestion (μSv)} = {}^{222}\text{Rn conc.(BqL}^{-1}\text{)} \times 60\ \text{L.y}^{-1} \times 10^{-3}\ \text{m}^3\ \text{L}^{-1} \times 3.5\ \text{n Sv Bq}^{-1} \quad (3)$$

RESULTS

The radon concentration in different types of water samples was estimated using radon emanometry in the Mysore city. Radon concentration varies from below detection limit (BDL) to 643.9 BqL^{-1} with a median of 15.8 BqL^{-1}. Distribution of ^{222}Rn activity in different types of water samples are tabulated in Table 1. Lake water and river water have a radon concentration with median of 0.1 BqL^{-1} and 0.31 BqL^{-1} respectively, which is below the quoted value of 0.4 BqL^{-1} by World Health Organization (WHO). Low radon concentrations are observed in tap and river water due to lack of major contact with radon emanating mineral material and also by aeration of radon gas to the atmosphere. Hence, the activity concentration of radon found in surface water is several orders of magnitude lower than the groundwater.[11,12] About 17% of the bore well samples are less than permissible limit of (300 $pCiL^{-1}$) 11.1 BqL^{-1}, which is prescribed by Environmental Protection Agency (EPA) and more than 80% of the samples are above the 11.1 Bq L^{-1} as shown in Figure 2.[13] Majority of the population uses the ground water like bore well water for the daily activities and drinking purpose. Compared to an Indian average, radon concentration in the 40% of the samples are within limit of 4-40 BqL^{-1}. The measured values of radon activity in the study area are comparatively higher than the other neighbor districts like Bangalore and Mangalore. In Bangalore the radon concentration in ground water varies from 5.3 BqL^{-1} to 283.4 BqL^{-1} with a median of 87 BqL^{-1} and in coastal Karnataka (Mangalore) it varies from 0.91-15.86 BqL^{-1}.[14,15] The distribution of ^{222}Rn activity in different types of water samples in geometric mean is shown in Figure 3. It is evident from the Figure 3, that the highest radon concentration observed in bore wells water than the surface water. The highest radon concentration of 643.9 BqL^{-1} observed in the Bandipalya village located behind the Chamundi hill is surrounded by granite rocks. Previous studies on soil and rock samples at Chamundi hill show highest concentrations of uranium and thorium radionuclides. As granite rock contains high radon concentrations, when ground water originates from granite formations radionuclides leach out with ground water. Due to this reason, the highest radon concentrations in bore well water samples have been observed.[6,16,17] The study area contains metabasalt-amygdaloidal, pillowed and meta-ultramafites means Dharwar super group granites and pink granite of Chamundi hill, which have an average uranium content of 3.0 ppm.[12,18] These granites are rich in radium and potassium radioactive elements. The bore wells dug up to a depth of about 30-92 m bgl,[19] the contact between water and the rocks in the drilled wells are responsible for the highest radon concentration. The result is correlated with similar work done at Extremadura, Spain having highest radon concentration of 1168 BqL^{-1} in ground water due to granitic and pre-cambrain ignesous bedrock.[20]

The dose was estimated due to ^{222}Rn through the ingestion and inhalation of water for the human population. Inhalation dose varies from BDL to 1.62 μSvy^{-1} for adults. Ingestion dose varies from BDL to 0.284 and BDL to 0.113 μSvy^{-1} for children and adult respectively. The

Table 1: Statistical distribution of ^{222}Rn activity (BqL^{-1}) in different types of water

Statistical variance	Bore well	Lake	Open well	Tap water	River
Frequency	68	10	7	15	3
Range	0.1-643.9	BDL-6.4	0.6-121.2	0.6-18.4	0.1-1.6
SD	123.74	1.95	44.94	5.95	0.81
Geometric mean	25.07	0.21	8.76	5.92	0.37
Median	33.14	0.10	8.99	6.79	0.31

BDL: Below detection limit, SD: Standard deviation

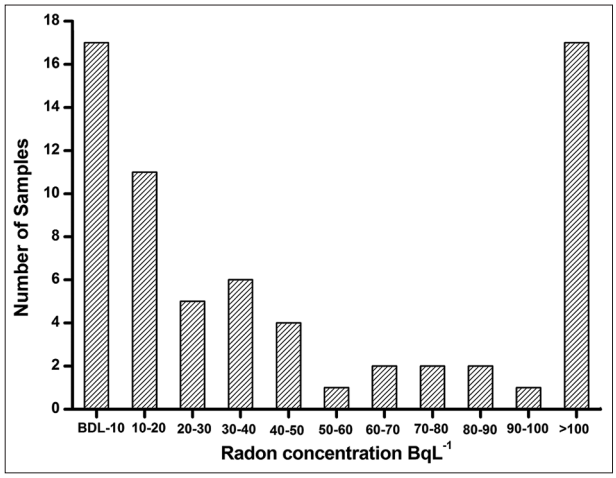

Figure 2: Distribution of radon concentration in Bore well

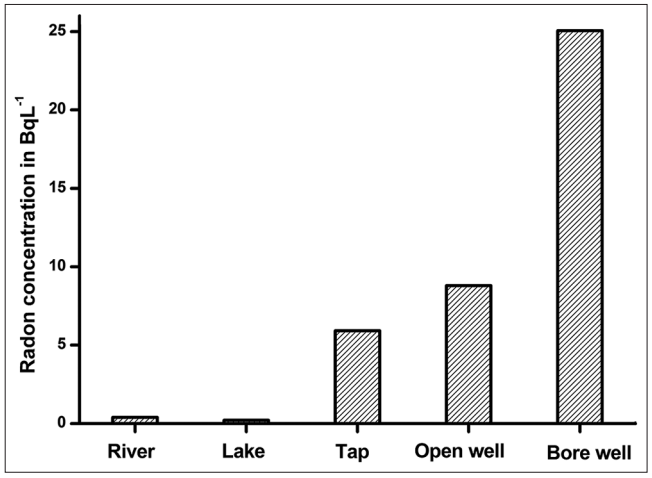

Figure 3: Distribution of radon concentration in water expressed in Geometric mean

Table 2: ^{222}Rn activity (BqL^{-1}) in water and the corresponding dose

Statistical variance	Radon conc. (Bq L^{-1})	Inhalation dose due to ^{222}Rn (μSvy^{-1})	Ingestion dose due to ^{222}Rn (μSvy^{-1})		Effective dose due to ^{222}Rn (μSvy^{-1})
	No. of samples=103		Children	Adult	
Range	BDL-643.9	BDL-1.62	BDL-0.284	BDL-0.113	BDL-1.76
Mean	53.05	0.149	0.026	0.010	0.162
Median	15.8	0.040	0.007	0.002	0.043
SD	91.27	0.275	0.048	0.019	0.298
25th percentile	4.95	0.012	0.002	BDL	0.013
75th percentile	63.4	0.160	0.028	0.011	0.173

BDL: Below detection limit, SD: Standard deviation

effective dose for an adult is found to vary from BDL to 1.76 μSvy^{-1} is tabulated in Table 2.

The estimated effective dose for an adult is very small compared to 100 μSvy^{-1} recommended by WHO.[12]

CONCLUSION

The ^{222}Rn concentrations in 80% of the bore well water samples are higher than the 11.1 BqL^{-1} prescribed by the EPA. But radon concentration is found to be less in surface water and tap water. Radon concentration in 40% of the bore well water samples are in the range of 4-40 BqL^{-1}. Consequently, the ingestion dose to the children, adult and the effective dose was found to be with a mean of 0.026, 0.01 and 0.162 μSvy^{-1} respectively, which is less than the 100 μSvy^{-1} as recommended by WHO.

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