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A Study of Radon Concentration in Drinking Water of Lolab valley, Kashmir Himalaya

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In the present study, radon concentration has been estimated in drinking water samples of different locations of Lolab in Kupwara district of Kashmir valley. A scintillation based detector, (Smart RnDuo) has been used to evaluate the radon concentration in collected drinking water samples. In addition, the surface contamination of gamma radiations at each location was detected using portable gamma ray detector (PM 1405, Polimaster Inc., USA). The radon concentration in drinking water samples has been found to vary from 3.27 to 59.50 BqL^{-1}, with an average of 23.65 BqL^{-1}.The annual inhalation dose varied from 0.01 to 0.15 $mSvy^{-1}$. The average annual inhalation dose was found to be 0.06 $mSvy^{-1}$ and it lies well within the permissible limits.

Keywords: Drinking water samples; Smart Radon Monitor; Radon concentration; Inhalation dose; Lolab Kashmir

1 Introduction

In addition to the microbial and the chemical contamination, the drinking water can also be contaminated due to radioactive elements which can pose risk to the human life. The radioactive contamination is usually low and needs to be evaluated for the drinking waters obtained from the ground water sources. The radioactive contamination of drinking water sources can be either artificial or natural. We can have the control on the artificial radioactive contamination but not on the natural contamination[1,2,29,30]. Among the radioactive contaminants, the radon is of particular interest from radiation point of view, as it contributes to more than 50% of the total natural background radiation dose received by the general populace [3-5]

The radon gas is an inert, colourless and odourless radioactive gas. Being inert, colourless and odourless makes it difficult to be detected by our senses. Thus, we need special type detectors for its detection. The three well known isotopes of radon are Radon (^{222}Rn), Thoron (^{220}Rn) and Actinon (^{219}Rn). Among these, the ^{222}Rn is of particular interest because of its half-life (~3.8 days), produced in the decay series of ^{238}U [2,6,7].

^{222}Rn is used in predicting and identifying the occurrence of the volcanic activities, fault dislocations and for hydrological research as well. However, because of its carcinogenic effects, it's high levels in indoor environments and in drinking waters is found to be a major hazard to humans. The present study is focussed on this aspect of ^{222}Rn.

The radiation dose associated with radon in drinking water, received by the humans, is via inhalation. In the present study, inhalation dose due to the ^{222}Rn concentration in groundwater has been quantified. The carcinogenicity of radon is well-established and is, in fact, positioned to be the second largest cause of lung cancer after smoking[8-10]

So, the water used in indoors for various purposes obtained from the various sources having elevated radon concentration may result in the high-level indoor radon concentration. Therefore, the ground water used in indoors is among the ways the radon enters our indoors[11]. Hence the quantification of radon in water becomes essential. The present research was carried in the Lolab valley of district Kupwara, Jammu and Kashmir. Although, some researches have been carried out in certain districts of the valley,[12-14], but no such study has been done so far in the present region. Hence this research is significant from the epidemiological point of view. Furthermore, the data will be used asa base line for future works in the region.

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2 Materials and methods

2.1 Study area

The present research was carried out in Lolab valley of Jammu and Kashmir. Fig. 1 shows the study area. Lolab is located in the northern Kashmir of Jammu and Kashmir and lies between the 34° 34′ 19″.10 north latitude and 74º 22′ 40″.55 east latitude. The lithology of the study area consists of the Salkhala group, forms the basement for the Tethyan sequence. It comprises carbonaceous slate, graphitic phyllite and schist, mostly pyritous, carbon aceous carbonate-commonly saccharoidal marble, calc-schist, non-carbonaceous slate, phyllite, schist and flaggy quartzite[15].

2.2 Assessment of surface contamination

In order to evaluate the surface contamination, we employed a portable Geiger-Muller (GM) counter radiation monitor (PM 1405, Polimaster Inc., USA) for the measurement of the ambient γ-radiations. The dose equivalent range (DER) of the said detector lies between 0.01μSvh^{-1} and 100mSvh^{-1}. A 5-min average was taken at each location by placing the detector one meter above the ground level.

2.3 Sample collection

Glass bottles of volume 60 ml, provided with the RnDuo monitor, were used to collect the water samples. All the precautionary measures were taken during the sample collection. Radon being the gas, could easily escape from the bottle during the sample collection and in order to avoid that the bottles were filled by dipping them into the water column and the lid cap was fixed inside the water column. Also, no air bubble was left inside the bottle, which could also result in the loss of radon gas. Immediately after the sample collection, the in-situ measurement was carried out in order to avoid the decay loss of radon.

2.4 Measurement of radon concentration

For the measurements of the radon concentration in the water samples, the smart RnDuo was employed. Smart Rn-Duo is a scintillation-based radon monitor[16]. A schematic of Rn-Duo is shown below in Fig 2. *Smart Rn-Duo* is an active, portable and

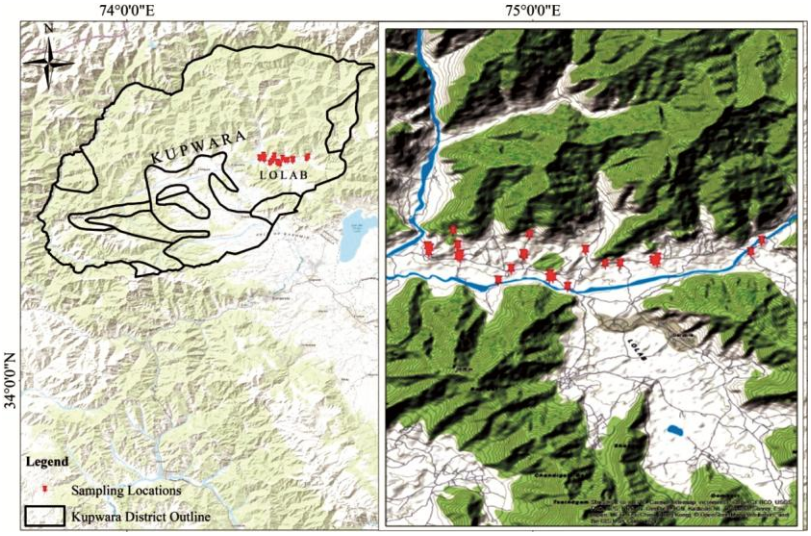

Fig. 1 — Source: Indian Topographic Map.

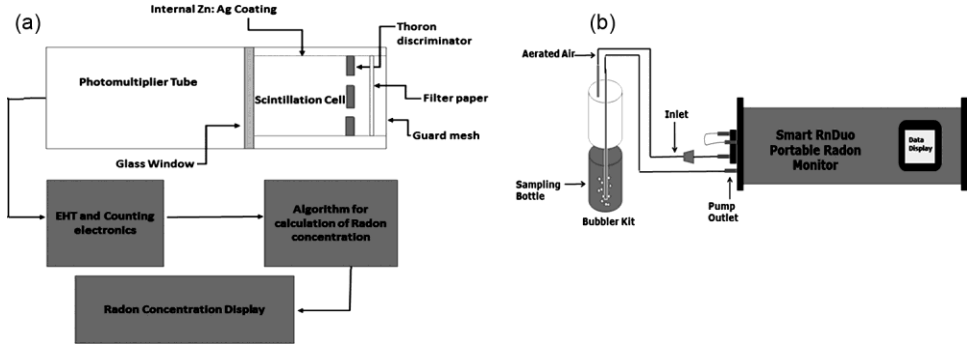

Fig. 2 — (a) A schematic of RnDuo monitor (b) A representation of the set-up of measurement of radon in water using RnDuo.

commercially available continuous radon monitor. It detects the ^{222}Rn, ^{220}Rn and the gross alpha in the air and its detection principle is based on the detection of alpha particles via scintillation process, where the ZnS:Ag is used as the scintillator[17]. The micro-controller of the detector has a radioactive decay algorithm implanted which converts the measured counts to the activity concentration. The radon sensitivity of the device is 1.2CPH $(Bqm^{-3})^{-1}$. The minimum and the maximum detection limit of the detector is 8 Bqm^{-3} at 1 sigma and 1 h counting cycle and 10M Bqm^{-3} respectively. The detector is calibrated each year at the Bhabha Atomic Research Centre, Mumbai. Trace gases and the humidity have no effect on the radon measurements of the detector.

In-situ radon measurements were carried out immediately after the sample collection. For each sample the detector was run for 1 h and four cycles were taken with each of duration of 15 min. Before each measurement the gases were flushed out by operating the pump for 5 min duration in open loop mode.

The equation given below was employed to get the radon concentration in the water

$$C_w = C_a \times (K + \frac{V_a}{V_w})$$

where C_w is the concentration of ^{222}Rn in water, C_a is the concentration of radon in air, K is the partition coefficient of radon in liquid with respect to air (0.25 for water) and V_a and V_w represent the volume of the air and water respectively.

2.5 Evaluation of annual inhalation dose

In the present investigation, we have evaluated the inhalation dose due to water, since about 90% of the dose associated with radon in drinking water is taken via inhalation rather than ingestion[18,19].

The annual inhalation dose is calculated according to parameters introduced by the UNSCEAR [20].

$$D_{inh} = {}^{222}Rn \times \phi \times F_R \times DCF_R \times T_{occ}$$

where, ^{222}Rn is the radon concentration in water, ϕ is the air to water concentration ratio (10^{-4}), F_R=(0.4) is the equilibrium factor between ^{222}Rn and its progenies.

DCF_R is the dose conversation factor for ^{222}Rn inhalation $(9nSv(Bqhm^{-3})^{-1})$ and T_{occ} is the mean indoor occupancy time $(\sim 7000hy^{-1})$[21-23].

3 Results and discussion

The results of various parameters like radon concentration, surface contamination are listed in the table 1 below.

A total of 26 water samples were collected from the different sources, like wells, tube wells and springs of the study area. Out of 26 samples, 21 samples were taken from the wells and 4 samples from the tube wells and 1sample from the spring. The radon concentration was found to vary from a maximum value of 59.50 BqL^{-1} to a minimum value of 3.27BqL^{-1} with an average of 23.65BqL^{-1}. The elevated radon concentrations are expected owing to the uranium oriented geology of the study region[31]. 19 samples (~73%) out of 26 were found to have radon concentrations exceeding the permissible limits of 11.1 BqL^{-1} prescribed by USEPA and no sample was found to cross permissible limits of 100 BqL^{-1} set by WHO. The samples which exceeded permissible limits of USEPA include 14 out of 21 taken from the wells, all the 4 samples taken from tube wells and one sample taken from a spring.

Correlation between various parameters like Gamma radiation versus Radon concentration and Radon concentration versus depth was framed out, shown below in Figs. 3 & 5, respectively. Fig. 4 shows the frequency distribution of radon concentration of radon in water. For the radon concentration versus depth, the Pearson's coefficient was found to be 0.33 (R^2 =0.07), which clearly indicates that the parameters are weakly correlated. This weak correlation is in good agreement with the existing literature which suggest that there is generally no correlation between radon concentration

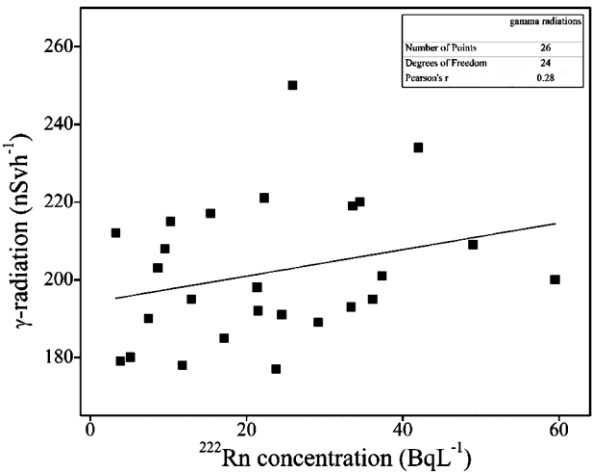

Fig. 3 — A Scatter Plot Showing the correlation between the γ-radiations and the ^{222}Rn concentration.

Table 1

Sample No	GPS location		Source	Depth	C_w	Inhalation dose
	Latitude	Longitude		(metres)	(BqL^{-1})	$mSvy^{-1}$
KUP01	34.545171	74.32764	Well	4.57	17.15	0.04
KUP02	34.546684	74.328173	Tube well	15.24	11.78	0.03
KUP03	34.547388	74.327185	Well	7.01	33.37	0.08
KUP04	34.545246	74.442713	Well	4.57	25.90	0.07
KUP05	34.54969	74.446553	Well	4.57	10.27	0.03
KUP06	34.541828	74.408189	Well	7.62	37.33	0.09
KUP07	34.543123	74.409298	Well	9.14	22.28	0.06
KUP08	34.541788	74.407707	Well	7.62	15.40	0.04
KUP09	34.541457	74.409078	Well	8.53	9.57	0.02
KUP10	34.536437	74.370983	Tube well	76.20	21.47	0.05
KUP11	34.535199	74.371975	Well	7.01	33.60	0.08
KUP12	34.531656	74.377175	Well	6.10	24.50	0.06
KUP13	34.535077	74.370771	Well	10.67	8.63	0.02
KUP14	34.540715	74.390601	Tube well	91.44	49.00	0.12
KUP15	34.540647	74.396004	Well	76.20	36.17	0.09
KUP16	34.546126	74.383584	Well	7.62	3.85	0.01
KUP17	34.538574	74.357072	Well	85.34	29.17	0.07
KUP18	34.552146	74.363568	Well	7.62	5.13	0.01
KUP19	34.544544	74.361367	Well	12.19	59.50	0.15
KUP20	34.543878	74.361757	Tube well	12.19	12.95	0.03
KUP21	34.53401	74.352466	Well	7.62	21.35	0.05
KUP22	34.543274	74.338739	Well	12.19	3.27	0.01
KUP23	34.543488	74.338084	Well	7.01	42.00	0.11
KUP24	34.547977	74.337898	Well	10.06	7.47	0.02
KUP25	34.553671	74.336335	Spring		23.80	0.06
KUP26	34.544276	74.338848	Well	6.10	34.53	0.09

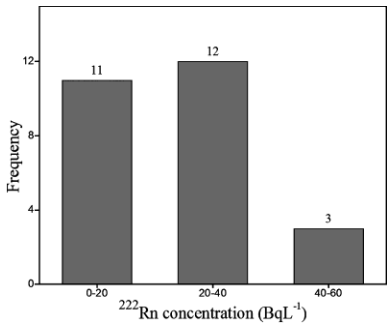

Fig. 4 — Frequency distribution of activity concentration of ^{222}Rn in water.

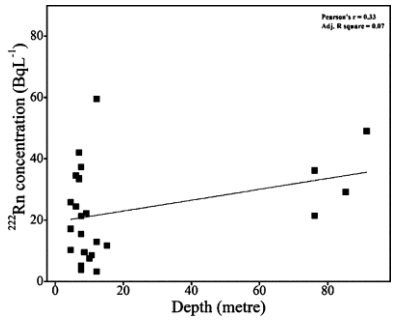

Fig. 5 — A Scatter Plot Showing the correlation between the ^{222}Rn concentration and the depth.

and depth. The radon concentration in the aquifer is solely dependent on the geology of the aquifer[24–28]. The correlation of the gamma radiation and the radon concentration is r = 0.28, which also shows that these parameters are weakly correlated.

Table 1 Radon concentration and the respective inhalation dose of 26 water samples of Lolab Kupwara.

4 Conclusions

Radon concentration in the samples varied from 3.27 BqL^{-1} to 59.50 BqL^{-1}, whereas the inhalation dose varied from 0.01 $mSvy^{-1}$to 0.15 $mSvy^{-1}$. The mean inhalation dose evaluated for the radon (^{222}Rn) was found to be 0.06 $mSvy^{-1}$ and it lies well within the permissible limits. Radon concentration in most of the samples in 19 (~73%) out of 26 samples exceeded the permissible limit of 11 BqL^{-1} set by USEPA and no sample exceeded the permissible limits of 100 BqL^{-1} set by WHO. The variation in the radon concentration may be due to the variation in the geology of the locations, and the elevated values of radon concentrations have direct relations with the geology of the study area.

From the results, it is concluded that the mean inhalation dose due to radon in the drinking water samples doesn't exceed the permissible limits but its use for various purposes in the indoors can contribute to the overall dose and thus increase the indoor radon concentrations. So, further research regarding the evaluation of the indoor radon concentration needs to be carried out. The areas of elevated radon concentration should follow the effective methods of radon mitigation, also the associated government water supplying agencies should conduct the programs about the awareness of radon, its mitigations, and its radiological hazards.

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