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Alpha activity in Indian thermal springs

K. Kant[1*], S.B. Upadhyay[2], S.K. Chakarvarti[3]

[1]*Department of Physics, KL Mehta Dayanand College for Women, Faridabad, Haryana, India-121 001*
[2]*Department of Physics, B.S.A. College, Mathura ,U.P. – 281 001*
[3]*Department of Applied Physics, N.I.T. Kurukshetra, Haryana, India-136 119*

ABSTRACT

Background: Dissolved radon is contained in natural water due to primordial uranium in rocks and soils with which it comes in contact. There is dual exposure from radon in water i.e. due to inhalation of the radon released from the water into the ambient air and through ingestion when water is used for drinking. As radon contaminated water adversely affects the health, it is therefore fundamental from health and hygiene point of view to measure radium concentration and radon exhalation rates in water.
Materials and Methods: LR-115, Type- II plastic track detectors were used to measure the radium concentration and radon exhalation rate in water samples collected from various thermal springs. The alpha tracks registered were counted by optical microscope at suitable magnification and converted into radium concentration and subsequently radon exhalation rates were measured.
Results: The radon concentration emanated from water samples (air borne) varied from 84 Bq m^{-3} to 827 Bq m^{-3} with an average of 429 ± 12.72 Bqm^{-3} and the dissolved radon concentration varied from 5.65 Bq l^{-1} to 55.66 Bq l^{-1} with an average of 28.88± 0.85 Bq l^{-1}. The radon mass exhalation rates varied from 2.37 mBq kg^{-1} hr^{-1} to 23.39 mBq kg^{-1} hr^{-1} with an average of 12.14 ± 0.36 mBq kg^{-1} hr^{-1} and surface exhalation rates from 52.34 mBq m^{-2} hr^{-1} to 515.29 mBq m^{-2} hr^{-1} with an average of 267.36 ± 7.93 from different thermal spring water samples. The radium concentration varied from 0.30 Bq l^{-1} to 2.93 Bq l^{-1} with an average of 1.52 ± 0.045 Bq l^{-1}.
Conclusion: Results indicate that the thermal spring water, which is also being used for drinking, is safe as far as radium concentration is concerned with the exception of a few isolated thermal spring sources. *Iran. J. Radiat. Res., 2005; 2 (4): 197-204*

Keywords: *Radium, radon, thermal spring, health, SSNTDs.*

INTRODUCTION

Radium is a naturally occurring radioactive element present in trace amounts throughout the Earth's crust. The decay of radium leads to radon in the environment (indoor and outdoor), soil, ground water, oil and gas deposits. It has been estimated that the radon, largely in homes, constitutes more than 50% of the dose equivalent received by general population from all sources of radiation, both naturally occurring and man-made (BEIR V 1990). A large body of human epidemiological data on occupational exposures to radon and its progeny yielded quite consistent risk factors down to dose encountered in some dwellings (BEIR III 1980). Evidence on radon and lung cancer is now available from about 20 epidemiological studies of underground miners, including 11 studies that provided quantitative information on the exposure-response relationship between radon and lung cancer risk (Lubin *et al.* 1995). Experimental animal studies and human studies of miners have clearly demonstrated an excess risk of lung cancer with exposure to radon (Lubin *et al.* 1994, BEIR IV 1988, Samet

***Corresponding author:**
Dr. K. Kant, Dept. of Physics, KL Mehta Dayanand College for Women, Faridabad, Haryana, India -121 001
E-mail: kkant_67@rediffmail.com

1989). The exposure of population to high concentrations of radon and its daughters for a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer (BEIR VI 1999). Dissolved radon is contained in natural ground water due to primordial uranium in rocks and soils with which it comes in contact (Sachs *et al.* 1981, Hess *et al.* 1978). There is dual exposure from radon in water i.e. due to inhalation of the radon released from the water into the ambient air and through ingestion when water is used for drinking. Some people who are exposed to radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer. The two diseases of principal concern associated with radon are stomach cancer from ingestion and lung cancer from inhalation (Mills 1990). As radon contaminated water adversely affects the health, it is therefore fundamental from health and hygiene point of view to measure radium concentration and radon exhalation rates in water, especially when present in high concentration. Various researchers have reported the results of radon and radium concentration measurements in natural spring water, thermal spring water, mineral water, public water supply, ground water etc. (Sasser 1977, Amrani and Cherouati 1999,Chauhan *et al.* 2001, Virk *et al.* 2002, Ramola *et al.* 2002, Al-Kazwini *et al.* 2003, Segovia *et al.* 2003, Valia *et al.* 2003, Kovacs *et al.* 2004).

As per available data in the literature, the radon monitoring in the ground water and thermal springs water in the Haryana state (India) has not been carried out. The water from thermal springs (monitored in the present study) is being used by indigenous inhabitants since long for drinking and other purpose. In the present work, radium concentration and radon exhalation rates were measured in the samples of hot spring water and ordinary water. The samples were collected from deep bores at various locations in the area and analysed for radium concentration and radon exhalation rates.

STUDY AREA AT A GLANCE

Radium concentration and radon exhalation rate measurements were carried out at different locations in Sohna town of District Gurgaon, Haryana State (India) (figure 1). The name Sohna has been derived from the gold dust (Sona), which was found after heavy rains in the beds of neighbouring torrents. The town is of great antiquity and is especially remarkable for its hot springs. These springs have linkage with

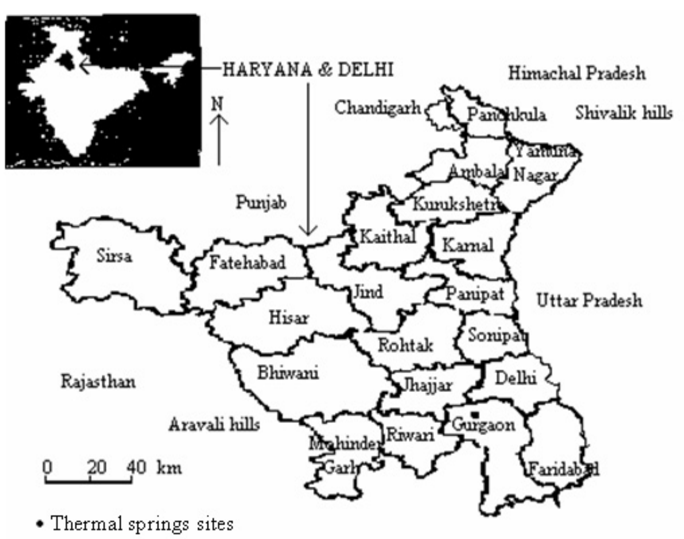

Figure 1. Geological map of the thermal spring water samples collection sites.

Indian mythology and are famous place for tourists and pilgrims. People visit these springs for pleasure and take bath for remedial purposes. Unconsciously they may be exposed to a large dose of radioactive emissions. From health and hygiene point of view it was extremely important to carry out radioactive measurements in these springs. The town is having an altitude of 230 meters. It lies in 28° 14′ 51′′ Northern Latitude and 77° 05′ East Longitude. It is situated in the foothills of mountain range known as Aravali Range. The temperature of water collected from various hot springs was recorded up to 47°C.

MATERIALS AND METHODS

For the measurement of radium concentration and radon exhalation rates, we have used the can technique (Abu-jarad 1988). The water samples were collected from the natural thermal springs in plastic containers. A known volume (100 c.c.) of water samples were kept in plastic cans and the LR-115, Type II plastic track detectors, used to measure the radium and radon concentration, were fixed on the bottom of the lid of each can with tape such that sensitive side of the detectors faced the specimen. The cans were tightly closed from the top and sealed. The LR-115 detectors were used for the measurements because of low background noise and the better contrast. The red-dyed 10 mm layer of sensitive cellulose nitrate film on an inert polymer base offers excellent contrast while visualising etched a-tracks. The geometrical parameters of the detectors and can were:

LR-115 type II plastic track detectors (2 cm × 2 cm),

Plastic cans with diameter = 7.6 cm and height = 9.9 cm

The exposure time of the detectors was 100 days. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5N NaOH solution at 60°C for one and half hour. The detectors were washed and dried and the tracks were counted using an optical Olympus microscope using Close Circuit TV (CCTV) camera and a monitor at magnification 600 X. Large number of graticular fields of the detectors were scanned to reduce statistical errors.

Calibration factor used was, 0.056 tracks $cm^{-2}\,day^{-1}$ = 1 Bq m^{-3} (Singh *et al.* 1997, Kumar *et al.* 2003).

The dissolved radon concentration in water was calculated using equation (1) used by various researchers (Somogyi *et al*. 1986, Al-Bataina *et al*. 1997).

$$C_w = C_a \lambda h T/L \qquad \mathbf{(1)}$$

where C_a = radon concentration in ambient air (Bq l^{-1})

λ = Decay constant for radon (h^{-1})

h = the distance from the surface of water to detector (m)

T = Time of exposure (hrs) and

L = the depth of the sample (m)

Radium concentration was calculated using equation (2) used by various researchers (Singh *et al*. 1998, Chauhan *et al*. 2001, Kant *et al*. 2003).

$$C_{Ra} = \rho h A / K T_e M \qquad \mathbf{(2)}$$

where ρ = Background corrected alpha track density due to radon (tracks cm^{-2})

h = Distance between the detector and top of the sample (m)

A = Surface area of the sample (m^2)

K = Sensitivity factor (tracks $cm^{-2}day^{-1}$ per Bq m^{-3})

M = Mass of the sample (kg)

T_e = Effective time of exposure (days)

Effective exposure time $T_e = T\,[1-e^{-\lambda Rn.T}]$

For large exposure time, $[1-e^{-\lambda Rn.T}]$ reduces to 1 and T_e = T (total time of exposure)

Exhalation rates (E_x) were calculated using the equations (3) and (4) used by various researchers ((Abu-jarad *et al.* 1980, Khan *et al*. 1992, Chen *et al*., 1993, Singh *et al*. 1998).

For mass exhalation rate,

$$E_X = \frac{CV\lambda/M}{T + 1/\lambda(e^{-\lambda T} - 1)} \quad (BqKg^{-1}h^{-1}) \qquad \mathbf{(3)}$$

and for surface exhalation rate

$$E_x = \frac{CV\lambda/A}{T + 1/\lambda(e^{-\lambda T} - 1)} \quad (Bqm^{-2}h^{-1}) \qquad \textbf{(4)}$$

where C = Integrated radon exposure (Bq m^{-3} h^{1})

V = Volume of air in can (m^3)

T = Time of exposure (hrs)

l = Decay constant for radon (h^{-1})

A = Area covered by the can or surface area of the sample (m^2)

RESULTS AND DISCUSSION

The calculated values of radium concentration, radon concentration (airborne and dissolved), mass and surface exhalation rates of radon for water samples collected from various thermal springs in Haryana State (northern India) are presented in table 1 and for ordinary water samples collected from various places in Haryana State

Table 1. Radium and radon concentration and radon exhalation rates in thermal spring water samples.

Sr. no.	Sample code	Radium conc. (Bq l^{-1})	Radon conc. (airborne) (Bq m^{-3})	Radon exhalation rates Mass (mBq kg^{-1} hr^{-1})	Radon exhalation rates Surface (mBq m^{-2} hr^{-1})	Radon conc. dissolved in Water (Bq l^{-1})
1.	Hot-1	0.30	84	2.37	52.34	5.65
2.	Hot-2	1.01	286	8.09	178.20	19.25
3.	Hot-3	0.85	241	6.82	150.16	16.22
4.	Hot-4	2.75	777	21.98	484.13	52.29
5.	Hot-5	2.41	682	19.29	424.94	45.90
6.	Hot-6	0.59	168	4.75	104.68	11.31
7.	Hot-7	0.30	86	2.43	53.58	5.79
8.	Hot-8	1.49	420	11.88	261.69	28.27
9.	Hot-9	2.83	800	22.63	498.46	53.84
10.	Hot-10	0.92	261	7.38	162.62	17.57
11.	Hot-11	2.08	588	16.63	366.37	39.57
12.	Hot-12	0.54	152	4.30	94.71	10.23
13.	Hot-13	1.10	311	8.80	193.78	20.93
14.	Hot-14	2.93	827	23.39	515.29	55.66
15.	Hot-15	2.59	738	20.88	459.83	49.67
16.	Hot-16	1.16	327	9.25	203.75	22.01
17.	Hot-17	1.99	563	15.93	350.79	37.89
18.	Hot-18	0.50	141	3.99	87.85	9.49
19.	Hot-19	1.94	548	15.50	341.45	36.88
20.	Hot-20 AM±SE*	2.06 1.52±0.045	582 429±12.72	16.46 12.14±0.36	362.63 267.36±7.93	39.17 28.88±0.85

* SE (standard error) = s/Ö N, Where s is SD (Standard Deviation) and N is the no of observations

Volume of water sample = 100cc

Mass of the water sample (M) = 0.1 kg

Surface area of the sample (A) = 45.4 ´ 10^{-4} m^2

Height of the sample = 2.1 cm

Volume of air in the can above the sample (V) = 354 ´ 10^{-6} m^3

are presented in table 2. The radon concentration emanated from water samples (air borne) varied from 84 Bq m^{-3} to 827 Bq m^{-3} with an average of 429 ± 12.72 Bqm^{-3} and the dissolved radon concentration varied from 5.65 Bq l^{-1} to 55.66 Bq l^{-1} with an average of 28.88 ± 0.85 Bq l^{-1}. The radon mass exhalation rates varied from 2.37 mBq kg^{-1} hr^{-1} to 23.39 mBq kg^{-1} hr^{-1} with an average of 12.14 ± 0.36 mBq kg^{-1} hr^{-1} and surface exhalation rates from 52.34 mBq m^{-2} hr^{-1} to 515.29 mBq m^{-2} hr^{-1} with an average of 267.36 ± 7.93 from different thermal spring water samples. The radium concentration varied from 0.30 Bq l^{-1} to 2.93 Bq l^{-1} with an average of 1.52 ± 0.045 Bq l^{-1}. In ordinary water samples the radon concentration emanated from water samples

Table 2. Radium and radon concentration and radon exhalation rates in drinking (ordinary) water samples.

Sr. no.	Sample code	Radium conc.(Bq l^{-1})	Radon conc. (airborne) (Bq m^{-3})	Radon exhalation rates Mass (mBq kg^{-1} hr^{-1})	Surface (mBq m^{-2} hr^{-1})	Radon conc. dissolved in water (Bq l^{-1})
1.	DW-1	0.24	67	1.89	41.75	4.51
2.	DW-2	0.29	82	2.31	51.09	5.51
3.	DW-3	0.32	92	2.59	57.32	6.19
4.	DW-4	0.12	33	0.93	20.56	2.20
5.	DW-5	0.42	119	3.36	74.15	8.00
6.	DW-6	0.25	72	2.03	44.86	4.84
7.	DW-7	0.30	84	2.37	52.34	5.65
8.	DW-8	0.07	20	0.56	12.46	1.34
9.	DW-9	0.24	69	1.95	42.99	4.64
10.	DW-10	0.21	59	1.66	36.76	3.97
11.	DW-11	0.16	46	1.30	28.66	3.09
12.	DW-12	0.46	131	3.70	81.62	8.81
13.	DW-13	0.25	72	2.03	44.86	4.84
14.	DW-14	0.55	157	4.43	97.82	10.56
15.	DW-15	0.18	52	1.47	32.40	3.50
16.	DW-16	0.44	125	3.53	77.89	8.41
17.	DW-17	0.34	98	2.76	61.06	6.59
18.	DW-18	0.14	39	1.10	24.30	2.62
19.	DW-19	0.39	112	3.16	69.79	7.53
20.	DW-20 AM±SE*	0.31 0.28 ± 0.006	87 80.8±1.77	2.45 2.28 ± 0.05	54.21 50.34 ± 1.10	5.85 5.43 ± 0.12

* SE (standard error) = s/Ö N, Where s is SD (Standard Deviation) and N is the no of observations
Volume of water sample = 100cc
Mass of the water sample (M) = 0.1 kg
Surface area of the sample (A) = 45.4 ´ 10^{-4} m^2
Height of the sample = 2.1 cm
Volume of air in the can above the sample (V) = 354 ´ 10^{-6} m^3

(air borne) varied from 20 Bq m^{-3} to 157 Bq m^{-3} with an average of 80.80 ± 1.77 Bqm^{-3} and the dissolved radon concentration varied from 1.34 Bq l^{-1} to 10.56 Bq l^{-1} with an average of 5.43 ± 0.12 Bq l^{-1}. The radon mass exhalation rates varied from 0.56 mBq kg^{-1} hr^{-1} to 4.43 mBq kg^{-1} hr^{-1} with an average of 2.28 ± 0.05 mBq kg^{-1} hr^{-1} and surface exhalation rates from 12.46 mBq m^{-2} hr^{-1} to 97.82 mBq m^{-2} hr^{-1} with an average of 50.34 ± 1.10 from different ordinary water samples. The radium concentration varied from 0.07 Bq l^{-1} to 0.55 Bq l^{-1} with an average of 0.28 ± 0.006 Bq l^{-1}.

The measurements indicate higher levels of radium and radon concentration in thermal spring water samples than in normal water. It can be seen from the results that the radon concentrations vary appreciably from sample to sample. It is due to the fact that the water samples collected from various sites may have different Uranium contents. The levels of radon even in ordinary water samples in Shivalik hills in northeast of Haryana, Aravali hills and slate mines in southwest of Haryana were found to be higher as shown in table 2. It may be due to higher uranium contents in the under ground soil and water of hilly areas. Our findings are similar results reported by other workers (Singh *et al.* 1998, Chobey *et al.* 2001).

The measurements indicate that the levels of radium and radon concentration in the drinking water samples and thermal spring water samples (tables 1 and 2) and are well below the internationally recommended upper safe limit of 40 Bq l^{-1} (ICRP 93, UNSCEAR 1982) except few thermal spring water samples. From the findings of our study it reveals that there is no serious radiation health hazard to the public taking bath in the open hot springs. The study also suggests the need for the storage of thermal spring waters in open tanks before being supplied to the indigenous inhabitants.

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