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Measurements of Mass and Surface Exhalation Rate from Soil of Eastern Haryana, India

Amanjeet[1*], Ajay Kumar[2] and Suneel Kumar[1]

[1]Department of Physics, Chandigarh University, Gharuan, Mohali, Punjab, 140413 India.

[2]Post Graduate Department of Physics, DAV College Amritsar, Punjab, 143001 India.

**(Corresponding author: panghal.aman99@gmail.com)*

Abstract

Radon is the inert gas which is important for indoor radiation dose. More than half of radiation dose received by human being from radon. Radon is the decay product of radium which depends upon the radioactivity in building materials. Radon exhalation rate from the building material is an important issue. The radon mass exhalation rate and thoron surface exhalation rate have been estimated by means of SMART RnDuo in surface soil samples collected from Eastern Haryana. The radon mass exhalation rate and thoron surface exhalation rate are varied from 9.8 to 34.1 mBq/kg/h and 170.5 to 542.8 mBq/m^2/s with average value 19.01 mBq/kg/h and 370.38 mBq/m^2/s, respectively.

Keywords: Radon Mass exhalation rate, Thoron Surface exhalation rate, Radium, Radioactivity

INTRODUCTION:

Natural radiations originate in the environment from the natural as well as manmade sources. Sources include cosmic radiation naturally occurring radioactive material such as radon, thoron and fallout from nuclear weapons testing and nuclear accident. The biggest source of natural background radiation is airborne radon. Indoor air quality is an important issue nowdays because an individual spend more than 80% of their time in houses (BEIR, 1999). Because of ignorance about it, this turns into a potential hazard for living things. In 1956 a term "Radiation Ecology" appeared to indicate this range of the wide field of nature worried with the evaluation of radioactivity in the earth. The improvement and consequent development of atomic vitality for military and quiet purposes has been joined by ecological issues (Mehta et al. 2014).

Soil is the prime source of natural radionuclides such as uranium, thorium and potassium which is used as the building material. Radon is a radioactive inert gas and is the heaviest of the inert gases with atomic number 86 and relative atomic mass 222. There exist quite a few other isotopes of radon besides ^{222}Rn; the most notable one are ^{220}Rn that is known as thoron and ^{219}Rn, which is known as actinon.^{222}Rn and ^{220}Rn are generated from the radioactive decay of radium isotopes, which in turn is a daughter product of natural decay of ^{238}U and ^{232}Th present in the earth's crust. Actinon is part of decay series of ^{235}U and has such a short half-life (4s) that is neglected in geochemical exploration. Uranium, thorium and radium are wide spread in the earth's environment and it exists in various geological formations in soil, rocks, plants, water and air.

Radon is inert gas which is colorless and odorless and is the decay product of radium which lies in the decay series of uranium. Radon is exhaled from the building materials and then inhaled by the residents. The radon exhalation rate depends upon the concentration of radium in soil and other building materials. Radon seeps out of the rocks and soil into the atmosphere (Akerblom et al., 1984) or into ground water or infiltrates into buildings. The rate of radon emanation depend on many factors, such as temperature, moisture content, activity concentration of radionuclide (^{238}U and ^{226}Ra) in soil and rock (Mayya et al., 1998) . Radon and thoron exposure can be enhanced or diminished by human activity, notably house construction. It may raise the concentration of airborne indoor radioactivity to unacceptable levels, especially in places having low ventilation rates places (Verma et al., 2014, Mehta et al., 2015). Basement sealing and suction ventilation reduce radon exposure. Some building materials like soil, rocks may emanate radon if they contain radium and are porous to gas (UNSCEAR, 2006). The indoor concentration of ^{222}Rn and ^{220}Rn depends on the crustal abundance of their parent elements and on their access to building interiors. Thus, types of soil and rocks around the abodes are the main source of ^{222}Rn and ^{220}Rn to which general population is exposed (UNSCEAR, 2000). The radon exhalated from the soil accumulate in indoor environment and adds to 55% inhalation dose According to BEIR reports (BEIR, 1999), the exposure of population to high activity of radon and its progeny a long stretch prompt to neurotic impacts like the respiratory practical changes and the event of lung cancer (ATDSR, 1999). Therefore, it is imperative to concentrate the radon discharge from the building materials.

Many researchers have been studied the radon and thoron in dwellings (Bajwa et al., 2008; Kant et al., 2009; Abu-Haija et al.; 2010; Mehra et al., 2011; Hussein et al., 2013; Singh et al., 2015) and exhalation rate in soil samples (exhalation rate in soil (Turham et al. 2008, Akhtar et al.2005, Shoeib et al.2014, Duggal et al. 2013, Mehta et al., 2015) in the world but Eastern Haryana, Northern India has not been studied for environmental radon and thoron so far. This study focused on radon mass exhalation rate and thoron surface exhalation rate

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from soil samples of Eastern Haryana in North India.

GEOLOGY OF STUDY AREA

Study area is located in Haryana state of India between 28° 40’ 30” to 29° 05’35” north latitude and

76°13’ 22” to 76° 51’ 20” east latitude. The altitude of district is about 220 meter from mean sea level. There is a gentle slope from north to south i.e.19 cm per km upto Jhajjar town in the northern part of the rohtak and there is considerable slope west to east. Jawahar Lal Nehru feeder and Bhalaut sub Branch are main canals. The study area is occupied by Indo-Gangetic alluvium. There is no surface features worth to mention. Physiographically the area is flat terrain. The area slopes towards northeast to southwest with an average gradient of 0.19 m/km. The soils of the district are fine to medium textured. It comprises sandy loam in Rohtak, Sampla, and Lakhan Majra blocks whereas it is loamy sand with occasional clay loam in Kalanaur and Meham Blocks. The soils of the district are classified as arid brown (Solemnized) and sierozem.

Figure 1: Geology of studied area.

MATERIALS AND METHODS

Mass Exhalation Rate

The emission of radon per unit area per unit time is called radon mass exhalation rate (J_m). Exhalation rate in soil sample can be measured using SMART RnDuo monitor that is consisting with closed accumulation chamber, which is a stainless steel cylinder with an inner height of 8 cm and radius 4.5 cm with a provision to attach a detector from upper side. SMART RnDuo monitoring the build up of radon concentration in the chamber at regular time intervals of one hour. The basic principle is based on detection of α particles, emitted from sampled radon and its decay progeny formed inside the detector volume by scintillation with ZnS(Ag). The chamber is the minimum residual volume in a chamber is maintained for accurate exhalation rate measurements. The instrument has a very good sensitivity and low detector volume which is good for sample analysis. In radon measurement mode, the thoron entry at the detector inlet is cut-off by diffusive sampling through pin hole. The alpha scintillations from radon and its decay products formed inside the cell are continuously counted for a user-programmable counting interval by the PMT and the associated counting electronics. The alpha counts obtained are processed by a microprocessor unit as per the developed algorithm to display the concentration of radon (Sahoo et al. 2011). The response time of SMART RnDuo is about 20 min for 63% of chamber radon concentration and 40 min for 95% of chamber radon concentration. Then by least square fitting method the build-up radon oncentration C(t) in Bq/m^3 at time t is assessed inside the chamber and radon mass exhalation rate J_m is then obtained by a given equation (Sahoo et al. 2007):

$$C(t) = \frac{J_m M}{V\lambda_e}\left(1 - e^{-\lambda_e t}\right) + C_0 e^{-\lambda_e t} \qquad (1)$$

where J_m represents the radon mass exhalation rate in (Bq/kg/h), M is the mass (kg) of soil sample, V is the effective air volume (m^3) of the chamber including the volume of the scintillation cell, λ_e represents the effective decay constant which is sum of ^{222}Rn decay constant and any chamber leakage rate if exists and C_0 is the initial radon concentration in chamber at t=0..

Surface Exhalation Rate

In case of thoron (^{220}Rn) monitoring by scintillation based thoron monitor, program based sampling is carried out using a flow mode sampler connected to the pump inlet of the monitor. In a 15 min cycle, sampling pump is kept ON for initial 5 minutes which gives a measure of thoron and background, followed by a delay of 5 minutes which ensures near complete decay of thoron and then, last 5 minutes counting gives the measure of background counts for that cycle.

The ^{220}Rn surface exhalation rate (J_{st}) (Bq/m^2/s) in soil samples can be obtained from equilibrium concentration of thoron (C_T) (Bq/m^3) inside the chamber using following equation (Kanse et al.2013;Sahoo et al. 2014):

$$J_{st} = C_T\, V\lambda / A \qquad (2)$$

where V is the residual air volume (m^3) enclosed by the loop, λ is ^{220}Rn decay constant (0.012464 s^{-1}) and A is the surface area (m^2) of sample.

RESULTS AND DISCUSSION

Mass exhalation rate and surface exhalation rate in soil samples of Eastern Haryana, Northern India had been measured using SMART RnDuo monitor. The mass exhalation rate and surface exhalation rate in study area varies from 9.8 to 34.1 mBq/kg/h and 170.5 to 542.8 mBq/m^2/s with average value 19.5 mBq/kg/h and 368.1 mBq/m^2/s, respectively (Table 1). Mass exhalation rate is maximum in village Sudana with value 34.1 mBq/kg/h and minimum in village of Basana with value of 9.8 mBq/kg/h which is shown in fig 2 . Surface exhalation rate is highest in village of Chandi with value of 542.8 mBq/m^2/s and lowest in the village of Basana with the value of 170.5 mBq/m^2/s which is shown in fig 3. Mass exhalation rate is high in Sudana village which may be due to high concentration of indoor radon and surface exhalation rate in Chandi village which may be due to high concentration of indoor thoron. Indoor radon and indoor thoron concentration depends upon the activity of uranium and thorium in the building material and water. Uranium and thorium concentration in Eastern Haryana has been reported by Amanjeet et al. 2017. Uranium and thorium concentration in this region is within the safe limits and some village uranium and thorium concentration is high. This region is famous for agriculture and Yamuna river water is main source of irrigation. Yamuna is originating from Aravali Hill which brought down the soil from this hill which the main region radioactivity in this region. Concentration of uranium and radon in drinking water in Eastern Haryana has been reported by Panghal et al. 2017. Tosham region which is the known area of high radioactivity and indoor radon is the main reason of high exhalation rate in study region. High indoor radon and thoron concentration in Tosham region has been reported by Bajwa et al. 2009. In the study region, granite of Tosham hill is used as a building material for the construction of abodes. Granite shows the high concentration of thorium due to which surface exhalation rate may be high in dwellings of the study region.

Mass exhalation rate in the present study is comparable to Western Haryana reported by Mann et al. 2014 and higher than Ambala (Mehta et al. 2016) and Kuruskhtera (Chauhan et al.2002) while Mohali (Mehta et al. 2015), Kapurthala (Kumar and Kaur, 2014) and Malwa region (Mehra et al.2006) of Punjab have lower value of mass exhalation rate than Central Haryana while Himachal Pradesh (Singh et al.2017) and Uttar Pradesh (Zubair et al.2012) have comparable value of radon mass exhalation rates.

Table 1: Activity concentrations of radon mass exhalation rate and thoron surface exhalation rate in soil samples of Eastern Haryana, India.

Villages	Locations Code	Radon mass exhalation rate (mBq/kg/h)	Thoron surface exhalation rate (mBq/m^2/s)
Basana	RH-1	9.8	170.5
Lahli	RH-2	21.6	537.2
Nigana	RH-3	14.4	360.8
Pilana	RH-4	11.3	435.3
Sundana	RH-5	34.1	529.2
Chandi	RH-6	28.3	542.8
Indergarh	RH-7	15.3	456.3
Lakahan Majra	RH-8	13.6	195.2
Bedwa	RH-9	26.9	292.7
Ajab	RH-10	15.3	183.8
	Min	9.8	170.5
	Max	34.1	542.8
	Average value	19.01	370.38

CONCLUSION

The mass exhalation rate and surface exhalation rate in study area varies from 9.8 to 34.1 mBq/kg/h and 170.5 to 542.8 mBq/m^2/s with average value 19.01 mBq/kg/h and 370.38 mBq/m^2/s, respectively. The results in this study show that radiological risk due to natural radiations can be reduced by choices of appropriate building material.

Table 2: Comparison of radon mass exhalation rate and thoron surface exhalation rate in other region of India.

Sample Name	Location	Mass exhalation rate (mBq/kg/h)	Surface exhalation rate (mBq/m^2/h)	Reference
Soil	Eastern Haryana	19.01	370.38 mBq/m^2/s	Present Study
Soil	Amritsar, Punjab	2.23	74.4	Singh et al., 2008
Soil	Sangrur, Punjab	20.58	724.9	Mehra et al., 2006
Soil	Faridkot, Punjab	19.90	702.0	Mehra et al., 2006
Soil	Patiala, Punjab	14.78	520.4	Mehra et al., 2006
Soil	Mansa, Punjab	18.50	652.0	Mehra et al., 2006
Soil	Ludhiana, Punjab	12.84	451.8	Mehra et al., 2006
Soil	Moga, Punjab	10.98	386.4	Mehra et al., 2006
Soil	Bathinda, Punjab	14.54	500.69	Singh et al., 2005
Soil	Mohali, Punjab	1.36	28.3	Mehta et al., 2015
Soil	Malwa region, Punjab	6.4 -36.3	224-1278	Mehra et al., 2006
Soil	Pathankot Punjab	1.91 to 6.55	-	Kumar et al., 2014
Soil	Kapurthala Punjab	2.96 to 5.74	-	Kumar and Kaur et al., 2014
soil	Ropar dIstrict, Punjab	7.04	248.19	Singh et al., 2009
Soil	Tosham Ring, Haryana	7.69	255.9	Singh et al., 2008
Soil	Kurukshetra, Haryana	5.60	154.2	Chauhan and Chakarvarti, 2002
Soil	Ambala, Haryana	7.40	203.6	Chauhan and Chakarvarti, 2002
Soil	Ambala	1.76	39.92	Mehta and Shikha, 2016
Soil	Sirsa	11.44 to 42.66	210.48-785.03	Mann et al., 2014
soil	Yamuna nagar, Haryana	73	1683	Pundir et al. 2014
soil	Panchkula, Haryana	83	1892	Pundir et al. 2014
soil	Morni Hill, Haryana	12.66	446.63	Singh joga 2009
soil	Kala Amb, Haryana	7.61	268.54	Singh joga 2009
Soil	Delhi	1.13	12.4	Sonkawade *et al.* (2008)
Soil	Uttar prdesh	23.1		Zubair et al.2012
Soil	Jawalmukhi Thrust, Himachal Pradesh	.02417E-04 to 7.24148E-05		Thakur et al., 2015
Soil	Hamirpur Mineralaized Zone Himachal Pradesh	22.51 ± 2.2		Singh et al., 2016
Soil	Godda, Jharkhand	17.2-22.8	525.4-708.2	Singh et al.2010
rock	Jamtara, Jharkhand	18.3-23.4	543.4-756.4	Singh et al. 2010
soil	Chandigarh	6.15	216.87	Singh et al. 2009

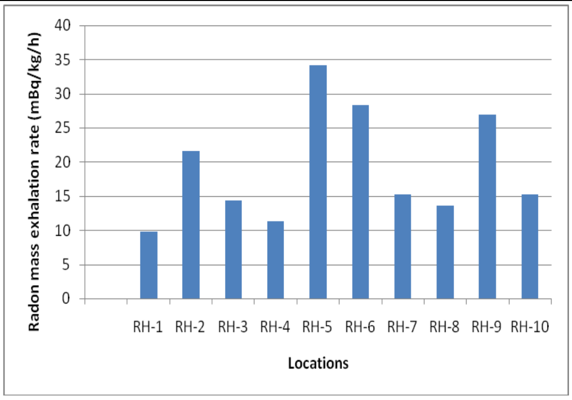

Figure 2: Variation of mass exhalation rate in Eastern Haryana.

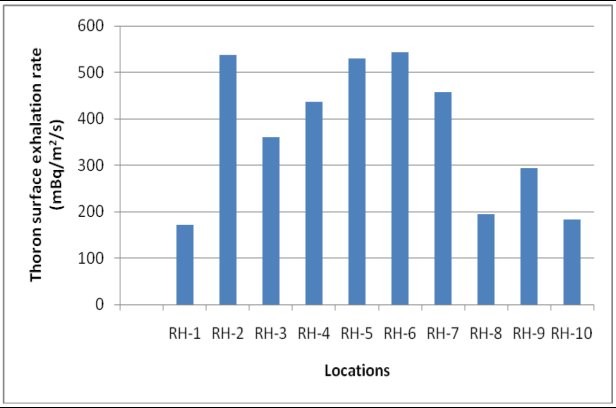

Figure 3: Variation of surface exhalation rate in Eastern Haryana.

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