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Assessment of Radon and Thoron exhalation rate from soil of historical city Panipat, India

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Abstract : Natural radioactivity exists everywhere on the earth and Uranium, thorium and potassium are the main source of radioactivity. 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 mass exhalation rate and surface exhalation rate have been estimated by means of SMART RnDuoin surface soil samples collected from the historical city Panipat and its surrounding areas.The mass exhalation rate and surface exhalation rate are varied from 14.82±0.3 to42.80±0.8mBq/kg/hand200.9 ± 61.5 to786.1 ± 116.8 mBq/m^2/s with average value 31.5 ± 0.8 mBq/kg/h and 467.5 ± 162.6 mBq/m^2/s, respectively.
Keywords: Radon, Thoron, Mass exhalation rate, Surface exhalation rate, Lung Cancer.

Introduction:

Background radiation is the ionizing radiation present in the environmentand originates from a variety of sources, both natural and artificial. 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[1].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[2].

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 exist in various geological formations in soil, rocks, plants, water and air.

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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[3] 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[4]. 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[5, 6]. 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[7]. 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[8]. The radon exhalated from the soil accumulate in indoor environment and adds to 55% inhalation dose According to BEIR reports[1], 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[9]. Therefore, it is imperative to concentrate the radon discharge from the building materials.

Many researchers have been studied the exhalation rate in soil samples[6,10,11,12,13]in the world but Panipat district of 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 from soil samples of Panipat district of Haryana in North India.

Geology of Study Area:

Panipat is an ancient and historical city in Haryana, India and this city is famous as city of Weavers and textile city. Panipat was the scene of three pivotal battles in Indian history. Panipat city is the biggest centre of shoddy yarn in the world. Panipat also has heavy industry, with an oil refinery and naptha cracking plant of the Indian Oil Corporation, a thermal power generation plant, Panipat Thermal Power Station of HPGCL, and a urea manufacture plant of National Fertilizers Limited. There are many tourist places like Panipat Museum, Hemu's Samadhi Place and Ibrahim Lodhi grave etc. Panipat district, lying in the east part of Haryana State and is located between 29° 09' 25":29° 27' 25" north latitude and 76° 38' 30":77° 09' 15" east longitudes. Panipat district forms a part of Indo-Gangetic plain and has two types of soils viz-tropical and brown soil (solemnized).The higher amount of organic matter has made these soils darker in color.Panipat district borders the state of Uttar Pradesh cross the Yamuna river in the east as shown in Fig.1. It mostly has alluvial deposits which resulted from tectonic changes effected due to uplift of Himalayan ranges. These deposits are composed of layers originating from alluvial silt and sand. The crust beneath these deposits includes Shivalik and tertiary residue with Gondwana and Cretaceous.

Fig 1: Geology of Panipat city and its surrounding 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 (Fig. 2). 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[14].The response time of SMART RnDuois 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 concentration 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[15]:

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

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.

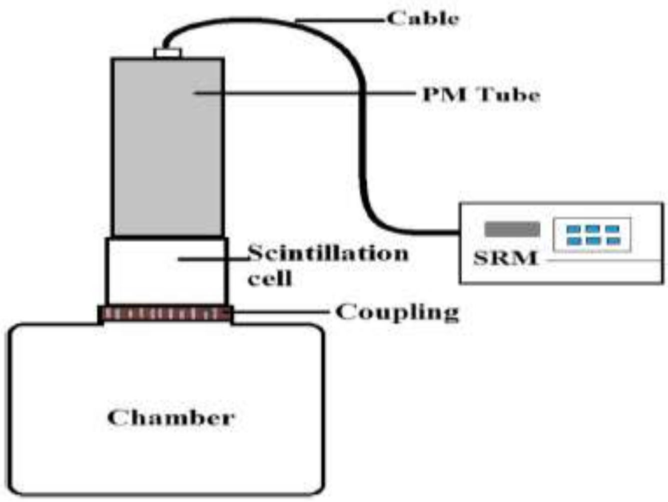

Fig. 2.Schematic diagram of radon mass exhalation setup.

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 (Fig 3). 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.

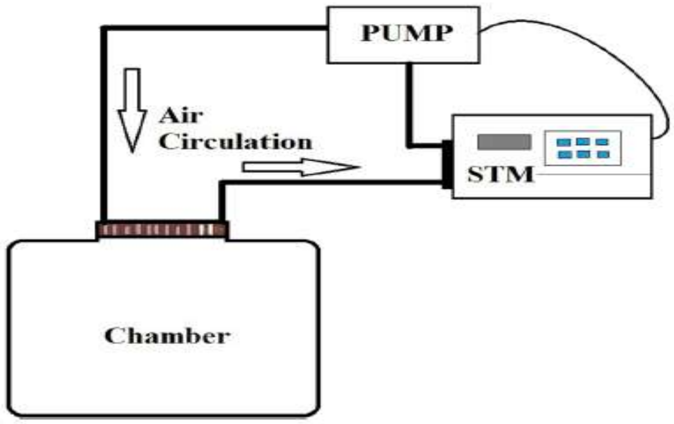

Fig. 3.Schematic diagram of thoron surface exhalation setup.

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[16, 17]:

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

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 ratein soil samples of historical city Panipat of Haryana and its surrounding area, Northern India had been measured using SMART RnDuo monitor.The mass exhalation rate and surface exhalation rate in study area varies from 14.82±0.3 to 42.80±0.8 mBq/kg/h and 200.9 ± 61.5 to 786.1 ± 116.8 mBq/m^2/s with average value 31.5 ± 0.8 mBq/kg/h and 467.5 ± 162.6 mBq/m^2/s, respectively (Table 1). Mass exhalation rate is maximum in village Mandhana with value 47.2 ± 0.9 mBq/kg/h and minimum in village of Patti Kalan with value of 12.8 ± 0.6 mBq/kg/h(Fig. 4).

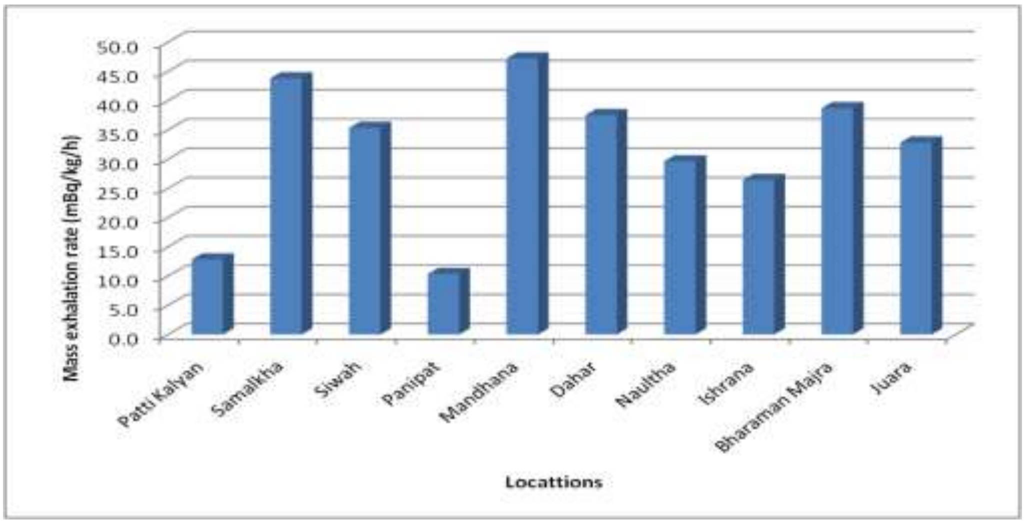

Fig 4 : Variation of mass exhalation rate in Panipat city and its surrounding area.

Surface exhalation rate is highest in village of Samalkha with value of 786.1 ± 116.8mBq/m^2/s and lowest in the village of Patti Kalan with the value of 200.9 ± 61.5 mBq/m^2/s (Fig. 5).

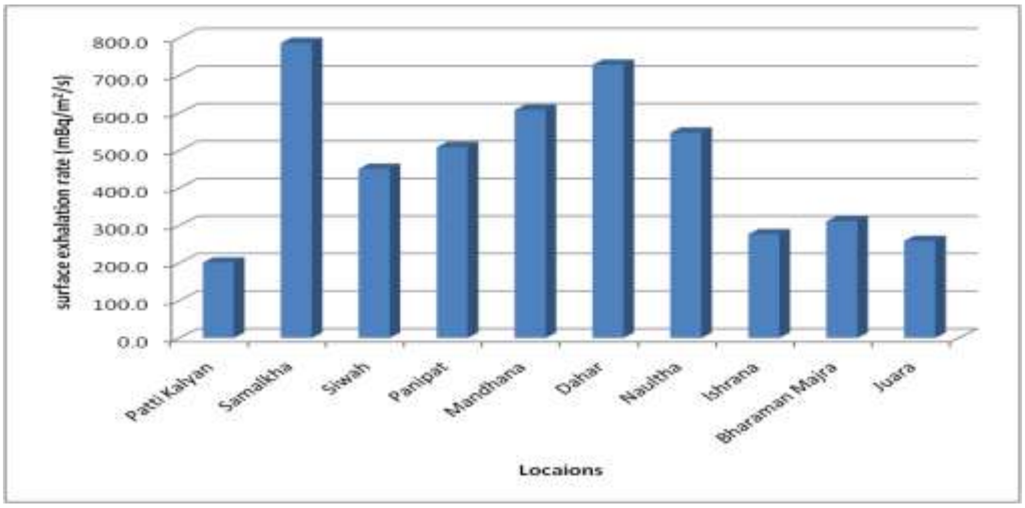

Fig 5: Variation of surface exhalation rate in Panipat city and its surrounding area.

Table 1. Activity concentrations of radon mass exhalation rate and thoron surface exhalation rate in soil samples of Historical city Panipat of Haryana, India.

Locations	Radon mass exhalation rate (mBq/kg/h)	Thoron surface exhalation rate (mBq/m^2/s)
Patti Kalan	12.8 ± 0.6	200.9 ± 61.5
Samalkha	43.8 ± 1.4	786.1 ± 116.8
Siwah	35.3 ± 1.0	450.7 ± 86.8
Panipat	10.4 ± 0.5	508.4 ± 89.2
Mandhana	47.2 ± 0.9	607.7 ± 106.7
Dahar	37.5 ± 0.7	728.4 ± 101.6
Naultha	29.6 ± 0.8	547.4 ± 93.7
Ishrana	26.4 ± 0.7	276.4 ± 74.8
Bharaman Majra	38.7 ± 0.3	310.8 ± 82.9
Juara	32.8 ± 0.9	258.4 ± 65.0
Min	12.8 ± 0.6	200.9 ± 61.5
Max	47.2 ± 0.9	786.1 ± 116.8
Average value	31.5 ± 0.8	467.5 ± 162.6

Mass exhalation rate is high in Mandhana village which may be due to high concentration of indoor radon and surface exhalation rate in Samalkha 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 this region has been reported[18]. 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 Panipat district has been reported by our group[19]. Mass exhalation rate and uranium in soil of Mandhana village is high which shows the positive correlation between mass exhalation rate and uranium concentration in soil. 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. 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. Comparison of mass and surface exhalation with other studies in presented in table 2.

Mass exhalation rate in the present study is comparable to Western Haryana[26] and higher than Ambala[25]and Kuruskhtera[24] while Mohali[6], Kapurthala[22] and Malwa region[20] of Punjab have lower value of mass exhalation rate than Central Haryana while Uttar Pradesh[28] have comparable value of radon mass exhalation rates (Table 2).

Table 2: Comparison of mass exhalation rate and 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	Panipat, Haryana	31.5	467.5$mBq/m^2/s$	Present study
Soil	Sangrur, Punjab	20.58	724.9	20
Soil	Faridkot, Punjab	19.90	702.0	20
Soil	Patiala, Punjab	14.78	520.4	20
Soil	Mansa, Punjab	18.50	652.0	20
Soil	Ludhiana, Punjab	12.84	451.8	20
Soil	Moga, Punjab	10.98	386.4	20
Soil	Mohali, Punjab	1.36	28.3	6
Soil	Malwa region, Punjab	6.4 -36.3	224-1278	20
Soil	Pathankot Punjab	1.91 to 6.55	-	21
Soil	Kapurthala Punjab	2.96 to 5.74	-	22
soil	Ropar dIstrict, Punjab	7.04	248.19	23
Soil	Kurukshetra, Haryana	5.60	154.2	24
Soil	Ambala, Haryana	7.40	203.6	24
Soil	Ambala	1.76	39.92	25
Soil	Sirsa	11.44 to 42.66	210.48-785.03	26
soil	Yamuna nagar, Haryana	73	1683	27
soil	Panchkula, Haryana	83	1892	27
soil	Morni Hill, Haryana	12.66	446.63	23
soil	Kala Amb, Haryana	7.61	268.54	23
Soil	Uttar prdesh	23.1		28
Soil	Jawalmukhi Thrust, Himachal Pradesh	.02417E-04 to 7.24148E-05		29
Soil	Godda, Jharkhand	17.2-22.8	525.4-708.2	30
rock	Jamtara, Jharkhand	18.3-23.4	543.4-756.4	30

Conclusion:

- The mass exhalation rate and surface exhalation rate in study area varies from 14.82±0.3 to 42.80±0.8 mBq/kg/h and 200.9 ± 61.5 to 786.1 ± 116.8 $mBq/m^2/s$ with average value 31.5 ± 0.8 mBq/kg/h and 467.5 ± 162.6 $mBq/m^2/s$, respectively
- The results presented in this work confirm that radiation exposure and attributed risk can be reduced by careful choice of building materials during construction.

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