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The *in situ* measurement and calculation of Exhalation rates of Radon and Thoron in Alappad region of Kollam district, Kerala, India

M.Midhun[1], R.S. Rejith[1], Samuel Mathew [1*], P.J. Jojo[2] and B.K. Sahoo[3]

1 Mar Thoma College, Thiruvalla, Kerala, India
2 Fatima Mata National College, Kollam, Kerala, India
3 Radiological Physics and Advisory Division, Bhabha Atomic Research Center,, Mumbai, India.

** Corresponding author. Tel: +91 9446066490, E-mail: plavila365@yahoo.co.in*

Abstract

Many a studies has been conducted on the exhalation rates of radon and thoron gases all over the world. According to UNSCEAR the second largest reason for the lung cancer is due to Radon, which is the major contribution for the natural radiation. Although radon is used as a tracer in studying movement of air and water masses on local and global scales, as a tool in mineral exploration, as an indicator of activity of fault zones and as an earthquake precursor, we are mostly concerned about its negative aspects. It is clear that the breathing air is contaminated by radon and thoron contributes more than half to the effective dose a member of the general public receives from all natural radioactive sources of ionizing radiation[5]. The half life of Radon (3.8 days) is long enough to enter in to the indoor regions and consequently increases the indoor radon concentration. In this paper we conducted detailed study about the surface exhalation rates and seasonal variations of radon and thoron from the Alappad region of Kollam district in Kerala. The pattern of variation is high concentration in winter and low concentration in summer. This is first time an *in situ* measurement is conducting to quantify the exhalation rate in this region. The measurement of exhalation rate is based on the gamma radiation level. The average gamma radiation level has been found to be 3μSvh^{-1}. The average seasonal exhalation rate of radon in summer is 265±117 Bqm^{-2}h^{-1}, in winter it is 271 ±115Bqm^{-2}h^{-1} and in monsoon it is 186±114 Bqm^{-2}h^{-1}. The average seasonal exhalation rate of thoron in summer is 19447±5437 Bqm^{-2}h^{-1}, in winter 22111±9564. Bqm^{-2}h^{-1} and in monsoon 21323±1426 Bqm^{-2}h^{-1}. The concentration of radon from various depths has also been studied and found that the soil gas amount reaches a steady value at 70-80 cm depth.

Index terms- in situ, exhalation

I. INTRODUTION

Terrestrially occurring natural radionuclide's are present in the earth's crust since its origin. Human beings those who lived in such area, which are usually known as high back ground radiation area (HBRA), are usually exposed to this natural radiations. Radon (^{222}Rn) is an- radioactive noble gas which is formed by the decay of ^{226}Ra, which is one of the nuclides formed in the disintegration series from ^{238}U. Before decaying or released in to the air the radon atoms entering in to the pore space from the mineral grain are transported by diffusion and advection though this space (Tanner, 1980). The main entry of radon in to atmosphere is by molecular diffusion. As an inert gas the radon can move freely through the soil from its source. Its range is determined by the factor such as rate of diffusion, effective permeability of the soil and its own half life. The diffusion length solely depends on the radon diffusion coefficient D (m2s-1) of the matrix soil and is given numerically as$\sqrt{(D / \lambda)}$, where λ is the decay constant of the isotope. Also the permeability depends on the grain- sized distribution, degree of compaction and water content of the soil. (Duranni 1997, Rogers 1991). Typically dry soil

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shows a diffusion length of 2m; moist soil shows 0.5m and wet soil of .05m.

Radon along with its daughter products are the major contributor of public exposure to natural radioactivity results a major health risk. The short lived daughters of the Radon are the agents of lung cancer (UNSCEAR, 1993). Contribution of radon and its progeny the total effective dose has been reported more than 50 % (UNSCEAR, 2000). In this perspective the measurement of natural radio activity is very important to determine the amount of natural and manmade activities. These affect the release of radioactive elements to the environment. Monitoring any such release important in the study of health assessment. The study about the radiological consequence is of twofold: first the effect of gamma photons on the body and second the effect on the lung tissue by ^{222}Rn decay products in the form of alpha particles. Due to this reason in the recent years substantial attention has been paid to radon and its progeny in the dwelling because of its apparent health application.

In India many research work has been conducted in the indoor measurement of Radon level in the dwellings (Kumar et al 1994; Mittal et al; 1998; Sharma and Virk, 1998; Singh et al; 2001, 2002; Ramachandran et al 2003). In this paper we conducted *in situ* measurement of Radon and Thoron level in the soil and detailed study about the exhalation rates of ^{222}Rn and ^{220}Rn in Alappad village of Kollam district of Kerala, India. Also measures the gamma radiation level of each locations, thereby we can calculate the effective dose per year. This first time, this type of detailed outdoor measurement of radiation level is conducted in this area. Besides of these studies soil gas measurement from various depths has been conducted and the seasonal variations of the exhalation rate also been studied.

A. Geology of the area

Alappad region is a coastal area of Kollam district of Kerala state in South India ranging from 9.023699 N and 76.516689 E to 9.128458 N and 76.466907 E. The coastal areas of Kollam region is well known for High Background Radiation Area (HBRA). There are four types of seasons in Kerala, which include winter, summer, south west monsoon and north east monsoon. The average temperature of Kerala normally ranges from 28^{0}C to 36^{0}C. The winter season starts from middle of November to beginning of February and the temperature of this season is almost 28^{0}C. The summer season normally from middle of February to May and the temperature is almost 36^{0}C. The state enjoys the monsoons in June, July, October and November with an average temperature of 33^{0}C. That means unlike other states in India there is not much variation in the temperature during the seasons.

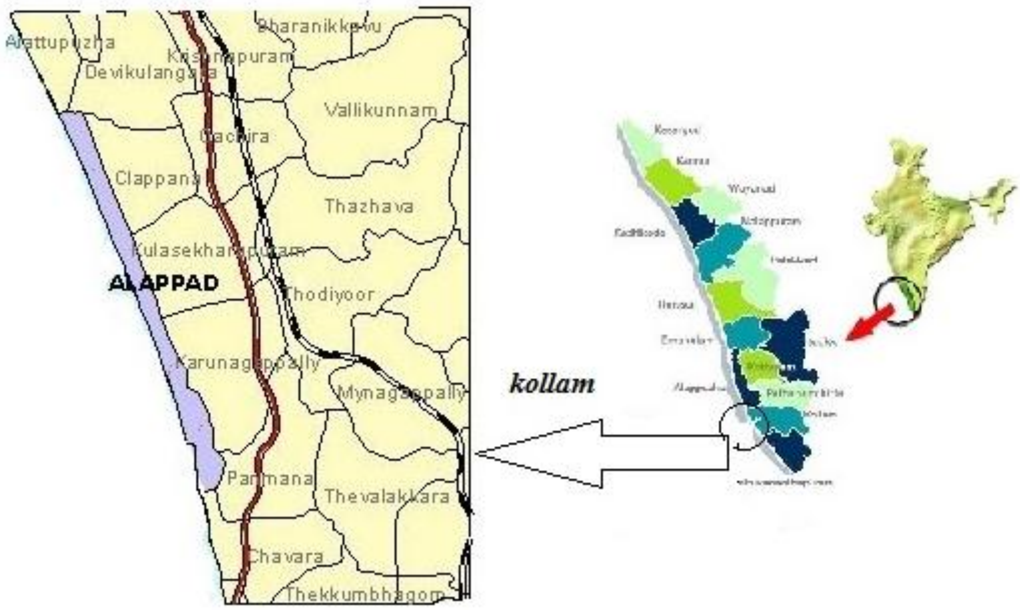

Fig1. map of Alappad

II. MATERIALS AND METHODS

The equipment is a technologically advanced ZnS(Ag) based real time radon and thoron monitor that automatically compensates the background counts due to decay products of radon/thoron and thus able to measure continuously the radon/thoron concentrations(Gaware, Sahoo 2011). In case of radon, air is sampled into the scintillation cell (150 cc) through a "progeny filter" and thoron barrier. The alpha scintillations from radon and its decay products formed inside the cell are continuously counted 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. In case of thoron, 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. Hence the interference of long lived decay product of thoron (^{212}Pb, half life of 10.6 hours) as well as due to radon (3.82 days) is not expected in this thoron monitor. Background counting and its subtraction from gross counts for each cycle have taken care of the possible interference of long lived alpha emitters. Since the detection principle is based on direct scintillation with ZnS:Ag, it does not have any interference from charge neutralizing species (such as humidity, CO_2, CH_4etc) and hence does not require any drying system unlike the case of electro-static collection based radon/thoron detector. This is one of the reasons for selecting this equipment for measurements in this location where humidity level is quite high.

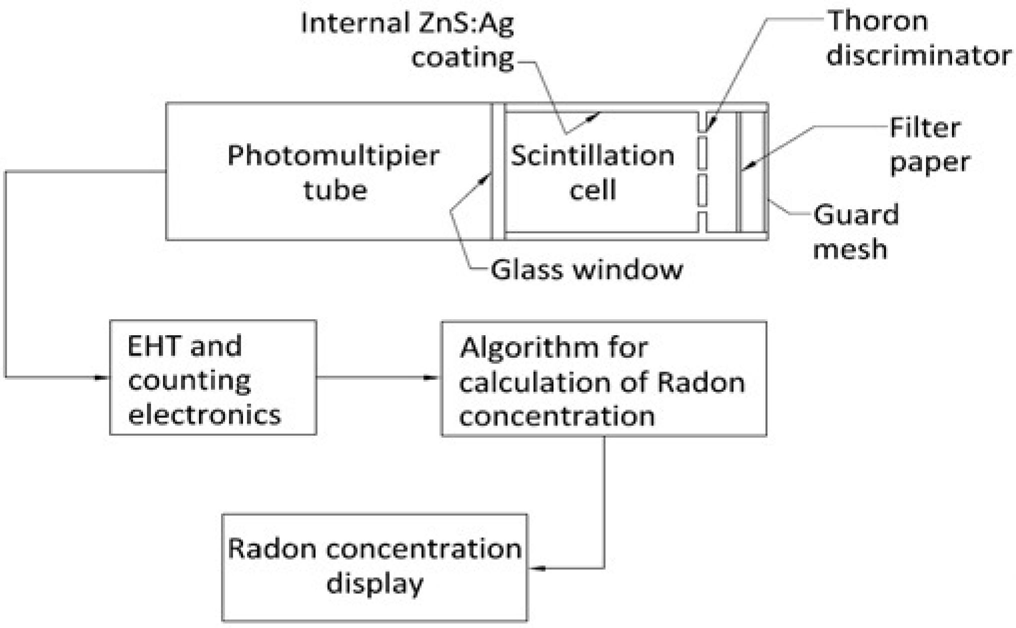

Fig.2 Block digram of SRM/STM

A. Measurement of Thoron exhalation

The in-situ measurement of thoron exhalation from the surface of beach sand was made using accumulator technique (Hosoda 2009, Sahoo 2010). An in-house developed accumulator set up was used for this measurement. Unlike the case of radon, a relatively small accumulator (5 cm diameter and 7 cm height) was used so as to validate the assumption of uniform concentration in the accumulator. The thoron sampling from the accumulator was carried out in flow mode using a closed loop setup, and then detection by thoron monitor (STM) connected in the loop. A representative location for a particular site was selected based on the gamma survey meter readings. Following the deployment of accumulator (1 cm burial depth), measurement was carried out for 1hour at an interval of 15 minutes. The average of the last three readings was taken to estimate the steady-state thoron concentration, C_e(Bq m^{-3}) in the accumulator. The value of C_e was used later to compute the thoron flux, J_T (Bqm^{-2}s^{-1}) from Eqn. below, obtained by mass balance (Hosoda 2011)

$$J_T = \frac{C_e V \lambda}{A} \quad (1)$$

where, λ is the thoron decay constant (0.0126 s^{-1}), V is the total volume i.e. sum of accumulator, detector and tubing volume (m^3) and A is the surface area (m^2) of the sand matrix enclosed by the accumulator.

B. Measurement of Radon exhalation

The measurements of in-situ radon exhalation were carried out by accumulator technique with application of exponential growth curve analysis (10). In this method a cylindrical accumulator (15 cm dia. and 15 cm height) coupled with the continuous radon monitor (SRM) was placed on the soil surface. SRM instrument was used in diffusion mode for radon measurement and the gas entry point to the instrument chamber is at a height of 15cms from the soil surface. Hence, the interference of thoron (if present in soil) is avoided. Radon concentration that builds up inside the accumulator was recorded every 15 minutes and the measurements continued for 5 – 7 hours. The radon concentrations (Bqm^{-3}) measured with time elapsed (t) with respect to start of the accumulator was plotted. The radon growth equation in a typical accumulator is given by the exponential relation (10)

$$C(t) = \frac{J_R}{(V\lambda_e)(1-e^{-\lambda_e t})} + C_0 e^{-\lambda_e t} \qquad (2)$$

where C(t) is radon concentration (Bq m^{-3}) at time, J_R is the measured radon flux from soil (Bq m^{-2} h^{-1}), is volume of the accumulator (m^3), λ_e is the effective decay constant (h^{-1}) of radon for the given set up which is sum of radon decay constant, leakage rates(if any) and back diffusion rate for the set up . A is the area of soil surface covered by accumulator (m^2) and C_0 is the radon concentration inside the accumulator at t=0.Experimentally obtained radon build up data can be plotted against the exponential decay equation available in the software origin.

$$Y(x)=Y_0 + A_1 e^{-x}/_{t1} \qquad (3)$$

we get the fitting parameters Y_0 ,$A_1$and t_1. Comparing the equations (2) and(3) we get the radon surface exhalation rate $J_R=Y_0V\lambda_e/A$ and effective decay constant λ_e =1/t_1. Figure.2 shows the typical plot of radon build inside the accumulator.

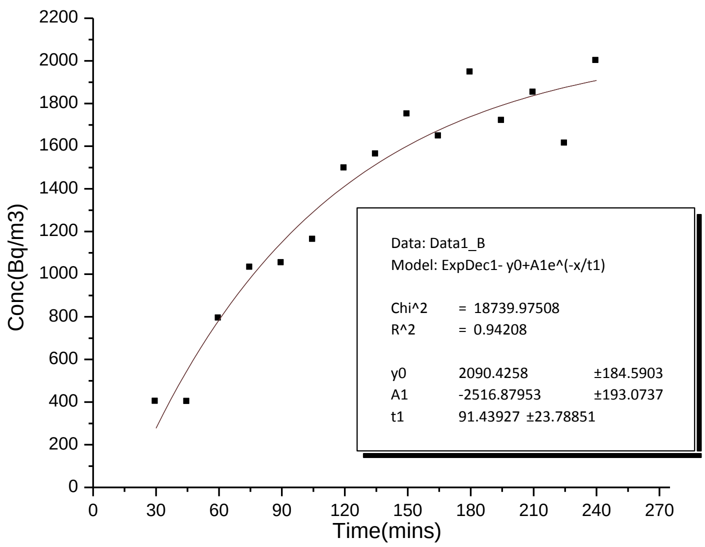

Fig.3 Least square fitting of Eq. (2) to data plotted between radon concentrations

III. RESULT AND DISCUSSION

Table.1 Exhalation data's of Radon and Thoron

Seasons	Radon exhalation rate($Bqm^{-2}h^{-1}$)			Thoron exhalation rate($Bqm^{-2}h^{-1}$)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Summer	378 ±112	179 ± 52	265 ±117	40407 ±5123	4106 ±3012	19446 ±5437
Winter	384 ±174	181 ± 42	271 ±115	39031 ±4325	4415 ±1243	22111 ±9564
Monsoon	234 ± 92	146 ± 23	185 ±114	40282 ±5215	14733±5127	21322 ±1426
Yearly	815 ±213	11 ± 9	175 ±97	42282 ± 6251	4006 ±1432	21027 ±1542

The table shows the data's of exhalation rates of radon and thoron in various seasons from the region of Alappad, Kollam district. The graph shows the exhalation rates of thoron is greater than radon which emphasises the thorium deposit in the beach sands. The study shows there are not many variations in the exhalation rates as per the season. This is may be because of there is not much difference in the temperature during various seasons in Kerala. An average of 32^0C of temperature throughout the year. Hence there surface exhalation rate is not much affected during summer and winter. There is small variation in the exhalation of radon during the south west monsoon season (June-July). This is may be because of moisture content in the beach sand is much higher which affect the transportation of Radon. So the emanation of gases may be affected. But there not much variation has been found in the exhalation of thoron gases.

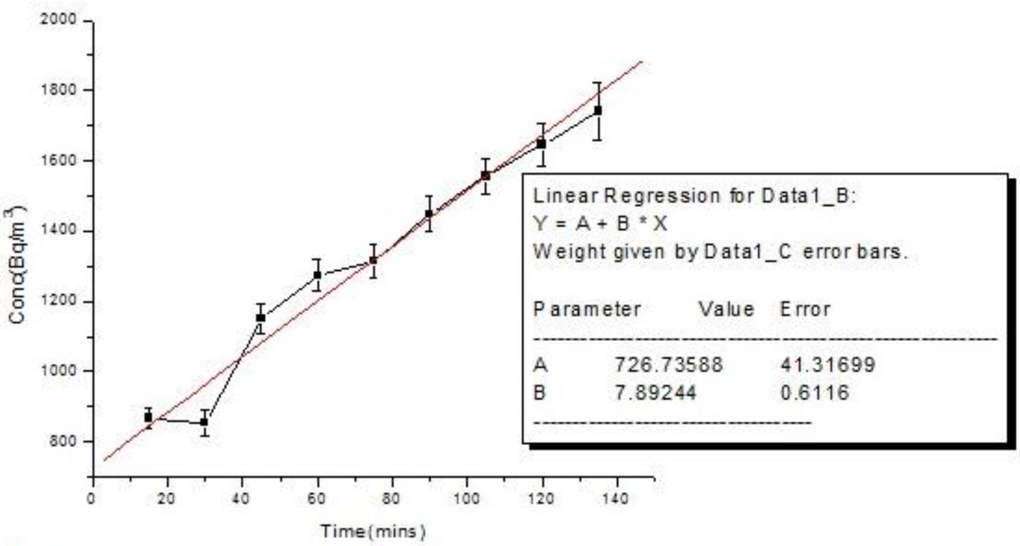

Fig.4. the building conc: of radon in the chamber

The fig4 shows the building of radon concentration in the chamber with time from a particular location of Alappad village. The value of the slope B is given by the graph which gives the exhalation rate by using the equation$J_R = BV / A$, where V and A refers the total air volume in side device and the surface area of the chamber.

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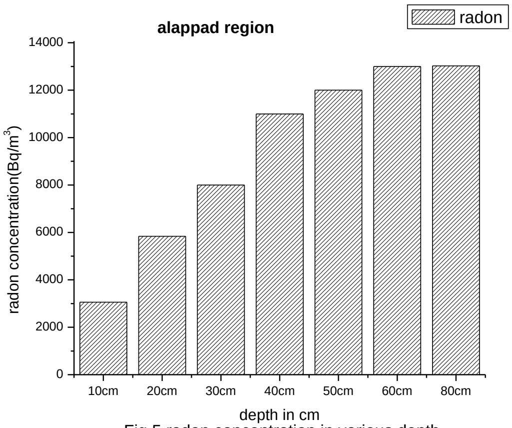

Fig.5 radon concentration in various depth

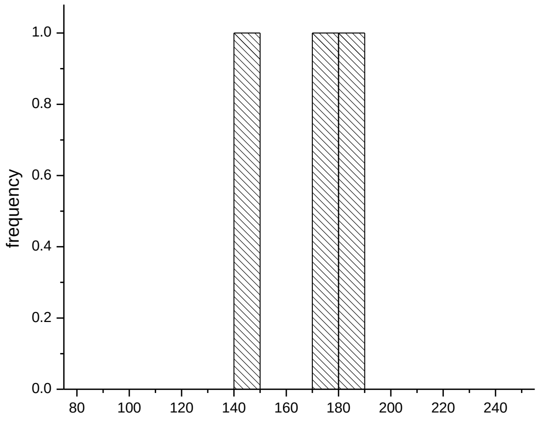

Fig.6.Frequency distribution of radon exhalation rates

The fig5 represents the concentration of radon in various depths. The measurement has done by the use of soil probe method. The measurement shows after a particular depth (~ 80cm) the concentration becomes almost steady. The fig.6 represents the frequency distribution of radon exhalation rates in various seasons.

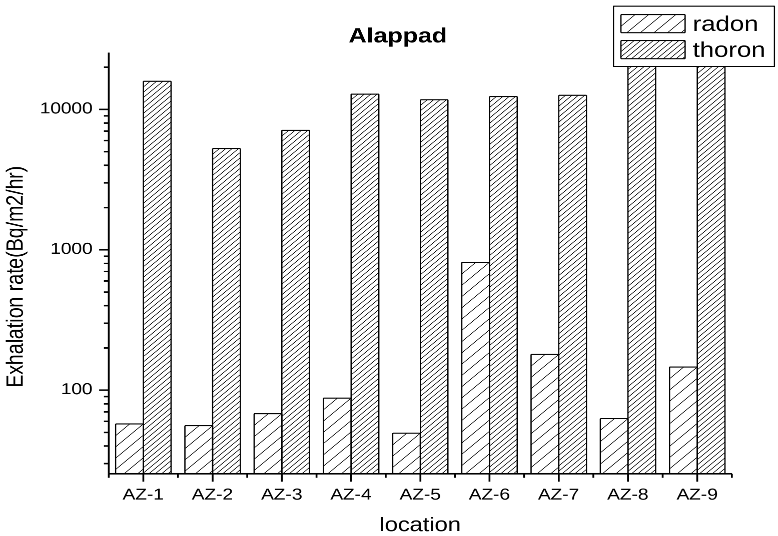

Fig.7 exhalation rate of both radon and thoron

The fig7 shows the exhalation rates of Radon and Thoron in the Alappad village. The exhalation rate of Thoron is much higher than the radon exhalation rate which establishes the Thorium deposit in the coastal area.

IV. ACKNOWLEDGEMENT

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REFERENCES

[1] The World Health Organization. Radon and cancer. Fact Sheet No.291 (2005). Available on http://www.who.int/mediacentre/factsheets/fs291/en/index.html

[2] The World Health Organization. WHO hand book on Indoor Radon (2009). ISBN 978-92-4-154767-3. Available on http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf

[3] United Nations Scientific Committee on the Effect of Atomic Radiation,UNSCEAR. Sources and effects of ionizing radiation. Vol I: sources (New York: United Nations)(2000). ISBN 92-1-142238-8

[4] United Nations Scientific Committee on the Effect of Atomic Radiation,UNSCEAR. Effects of ionizing radiation. Volume I: sources-to-effects assement for radon in homes and workplaces (New York: United Nations)(2006). ISBN 978-92-1-142263-4

[5] Janja Vaupotic, Igor Celikovic, Nata Smrekar, Zora S. Zunic and Ivan Kobal (2008): Concentrations of 222Rn and 220Rn in Indoor Air. Acta Chim. Slov. 55, 160-165.

[6] Yuji Yamada, Quanfu Sun, Shinji Tokonami,Suminori Akiba, Weihai Zhuo, Changsong Hou,Shouzhi Zhang, Tetsuo Ishikawa, MasahideFurukawa, Kumiko Fukutsu, Hidenori Yonehara(2006): Radon-Thoron Discriminative Measurements in Gansu Province, China, and their Implication for Dose Estimates. *Journal of Toxicology and Environmental Health,* Part A, 69:723-734

[7] JCH Miles,CB Howrath,N Hunter (2012): Seasonal variation of radon concentration in UK homes. Journal of Radiological Protection.32, 275-287

[8] J.J.Gaware, B.K.Sahoo., B.K.Sapra., Y.S.Mayya., 2011. Development of online radon and thoron monitoring systems for occupation and general environments. BARC News Letter. Issue No: 318, 45 -51

[9] M.Hosoda. A.Sorimachi., Y.Yasuoka. T.Ishikawa, S.K.Sahoo, M.Furukawa, N.M.Hassan, S.Tokonami and S.Uchida. Simultaneous measurement s of radon and thoron exhalation rate and comparison with values calculated by UNSCEAR equation. J. Radiat. Res **50** 333-343(2009)

[10] B.K.Sahoo., Y.S.Mayya., 2010. Two dimensional diffusion theory of trace gas build up in soil chambers for flux measurements. Agric. and Forest Meteorol, 150, pp. 1211-1224

[11] M.Hosoda, M.Shimo, M.Sugino, M.Furukawa, and M.Fukushi. Effect of soil moisture content on radon and thoron exhalation. J. Nucl. Sci. Technol**. 44**, 664-672 (2007)