Measurement of Indoor Radon levels in Workplace using Solid State Nuclear Track Detectors (SSNTD)

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Abstract:

Indoor radon concentration measurement survey has been carried out in workplace of kafori campus of Alzaiem Alazhari university using solid state nuclear track detectors (SSNTD)type Radonalpha-C. The radon concentration determined and estimate an annual effective dose and working level month. The radon concentration levels varied from 260 ± 23 to 593 ± 36 Bq/m^3 and average value around between 393.50 for first floor to 471.60 for second floor. An annual effective dose found in varies value from 6.559 to 14.961 mSv.y^{-1} with mean value 10.637±1.097 mSv.y^{-1}. The radon concentration values and annual effective dose values in some samples are higher than the values of the reference value range, higher values may find nearest permissible range, where radon levels were varied in the building floors in order high level second floor, ground floor and first floor.

Keyword: radon, indoor radon, workplace

المستخلص:

تـم قيـاس تركيـز الـرادون داخـل مـكان العمـل بمجمـع كافـوري جامعـة الزعيـم الأزهـري باسـتخدام كواشـف الأثـر النـووي الصلـب مـن نوعـرادون ألفـا Radonalpha-C. تـم تحديـد تركيـز غـاز الـرادون وتقديـر الجرعةالسـنوية المؤثـرة ومسـتوى العمـل الشـهري. تراوحـت مسـتويات تركيـز غـاز الـرادون مـن 260 ± 23 إلى 593 ± 36 بيكريـل / م^{3}ومتوسـط القيمـة يـتراوح بـين 393.50 للطابـق الأول

إلى 471.60 للطابـق الثـاني. تختلـف الجرعـة السـنوية المؤثـرة الموجودةبقيمتهامـن 6.559 إلى 14.961 مليسيفرت/سـنة بمتوسـط قيمـة 10.637 ± 1.097 مـلي سيفرت/سـنة. قيـم تركيـز غـاز الـرادون وقيـم الجرعةالسـنوية المؤثـرة في بعـض العينـات أعـلى مـن مـدى القيمـة المرجعيـة, و القيـم الأعـلى قـد توجـد بالقـرب مـن المـدي المسـموح به،حيـث أختلفـت مسـتويات الـرادون العاليـةفي طوابـق المبنـى بترتيـب الطابـق الثـاني، الأرضي والأول .

Introduction:

Radon is a naturally occurring noble gas, radioactive gas, colorless, odorless, soluble in water, and chemically inert radioactive element. Radon was discovered in 1899 by the two scientists R. B. Ownes and E. Rutherford [1]. It produced from uranium decay series. There are three naturally produced isotopes of radon, the ^{222}Rn isotope produced from ^{238}U series where is starting from ^{238}U and ending with stable ^{206}Pb element, thoron or thorium emanation ^{220}Rn isotope produced from ^{232}Th series where is starting from ^{232}Th and ending with stable ^{208}Pb element, and action or actinium emanation ^{219}Rn isotope produced from 235U series where is starting from ^{235}U and ending with stable ^{207}Pb element, are all disintegrated by producing alpha particles [2,3].

The naturally radioactive radon gas (^{222}Rn) which has a half-life of 3.8 days, emanates from rocks and soils and tends to concentrate in enclosed spaces like underground mines or houses. It is present in the air outdoors and in all buildings, including workplaces. It is thus an inescapable source of radiation exposure both at home and at work. High radon levels in air can occur in buildings, including workplaces, in some geographical locations [4]. The higher concentration of these gases in indoors is due to the low pressure inside house than outside which tends to suck in these radioactive isotopes from the building material, soil and floor through cracks or gaps in the walls and floor [5]. Ionizing radiation represents electromagnetic waves and particles that can ionize, that is, remove an electron from an atom or molecule of the medium through which they propagate. Ionizing radiation may be emitted in the process of natural decay of some unstable nuclei

or following excitation of atoms and their nuclei in nuclear reactors, cyclotrons, x-ray machines or other instruments. For historical reasons, the photon (electromagnetic) component of ionizing radiation emitted by the excited nucleus is termed gamma rays and that emitted from machines is termed x rays. The charged particles emitted from the nucleus are referred to as alpha particles (helium nuclei) and beta particles (electrons) [6].

The SI units of radioactivity is Becquerel (Bq), it indicates disintegration of radioactive atom per second.

1 Becquerel (Bq) = 1 disintegration of radioactive atom per second

Radon concentrations in the air are measured as the amount of radioactivity (Bq) in a cubic metre of air (Bq/m^3). The average radon level outdoors is 5 Bq/m^3 and in the homes of the United Kingdom, for instance, is 20 Bq/m^3 of air.

The radioactive materials constructions are very important for the assessment of radiation exposure to human being since building materials as a source of radiation and also shield against outdoor radiation.

The effects of exposure to radon (and thoron) in homes and workplaces concluded that inhalation of radon and its decay products was carcinogenic mainly for the lungs [7]. Where decided to develop an up -to-date picture of the current knowledge on biological mechanisms of radiation actions relevant to disease development, particularly at low incremental doses and dose rates, their implications for the dose -response relationship for health effects at low doses, and thus their relevance for estimation of associated risks to health [8].

The purpose of this study to survey of Radon Concentrations in workplace project was to gather long-term (three months or longer) indoor radon test results, to identify previously unknown areas where radon gas exposure may constitute a health risk and build, over time, a map of indoor radon gas exposure levels.

Material and methods:

Time-integrated, continuous recording or instantaneous measurements of radon, usually the activity of radon gas, can be made. Owing to the large variability of indoor radon concentrations, measurements integrated over at least three months are required when the aim is to determine the annual average. As a rule, such systems are based on solid-state nuclear track detectors [9]. Radonalpha-C type nuclear trace detectors use a small piece of special plastic or film inside a container with a small defined opening. Air being tested diffuses through a filter covering a hole in the container. When alpha particles from radon and its decay products strike the detector, they cause damage tracks; the number of tracks is proportional to the radon concentration. At the end of the test period, the container is sealed and returned to a laboratory for reading. The radon exposure duration of an alpha track detector is usually 1 to 12 months. Study area: for workplace measurement of radon gas concentration, the building of alziaemalazhri university, kafori campus were study areas selected.

Procedures for the measurement of radon:

The radon gas concentration shall be measured using a detector capable of integrating the radon exposure continuously over a period of not less than three months. Suitable devices radonalpha-C detectors. These measurements must be carried out by a measurement service registered with the EPA [10].

30 dosimeter of Radonalpha-C detectors devices placed in building floors where study place includes the offices, computer laboratories and small halls. The dosimeter had been positioned away from doors, windows, heat sources and ventilation systems at about 1 meter from the floor and walls, at an optimal height of 1 to 1.5 meters. The exposure point of the dosimeter represents the vertex of an inverted conehaving an angle of 140 degrees. After the exposure period the films contained in the Radonalpha-C de-

tectors analyzed in Geoexsrls – Radon lab.

The calculation of Radon concentration:

The activity radon concentration (C_{Rn}) Bqm^{-3} can calculated by the following equation [11].

Where ρ the track density (track cm^{-2}) which produce in CR-39 surface, K is the diffusion constant and depends on geometry of the cup (α-track $cm^{-2}\ d^{-1}$ [Bq m^{-3}]) and T is the exposure time (day).

The working levels (WL):

The working levels (WL) was calculated from the following equation [12].

where (C_{Rn}) is the radon concentration, (F) is equilibrium equivalent concentration factor 0.4.

Annual effective dose:

The annual effective dose (H_E) $mSv.y^{-1}$ calculate by the following mathematical expression for indoor radon and its progeny:

where (C_{Rn}) is the radon concentration, (D) is the dose conversion factor equals 9×10^{-6} $mSvh^{-1}$ $[Bqm^{-3}]^{-1}$, (F) is equilibrium equivalent concentration (EEC) factor, equal 0.4 taken for indoor inhabitants, (O) is the occupancy factor which is equal to 0.8 and (T) is the indoor occupancy time is 24 h ×365 = 8760 h.

The working levels month (WLM):

The working level month (WLM) was calculated by the following relation

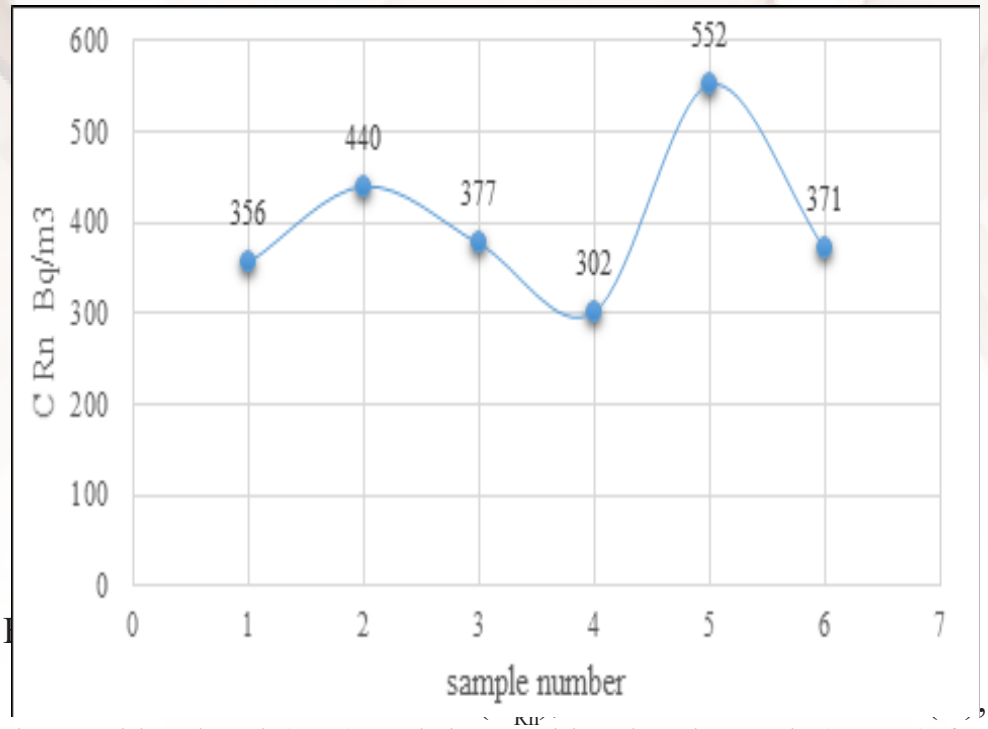
Where; WL is the number of working level, t is the exposure time (hour) which assumed that the exposure of 1 WL for 170 h produce 1 WLM [13].

Results and discussion:

The radon concentration (C_{Rn}), annual effective dose (H), the working level (WL) and the working level month (WLM) for detected samples of ground floor are shown in table 1 and figure 1, where the exposure period 144 – 147 days. The radon concentration in Bq/m^3 varies found in range from 302 ± 24 to 552 ± 33 with total C_{Rn} in kBq*h/m^3 at range from 1042 to 1906, the average radon concentration in ground floor was 399.67 ± 86.73. The radon reference levels for houses and buildings range 200 to 400 Bq/m^3[14], where the variation level sets were above 200 Bq/m^3. An annual effective dose (H) calculated, the varies between 7.619 and 13.926 mSv.y^{-1} the value of annual effective dose was high of reference value 4 mSv.y^{-1},when exposure of radon at the upper value of the national reference level of 300 Bq m^{-3} an annual effective dose of 4 mSv at work which recommended in ICRP [15] and more values located in ICRP recommended 3 – 10 mSv.y^{-1} [16]. The working levels (WL) and working level month (WLM) were variation range 0.033 – 0.060 and 0.002 – 0.003 respectively, the recommended nominal fatality and detriment coefficient at home and at work 3×10^{-4} per WLM [16].

Table 1: The concentration of radon gas in the ground floor

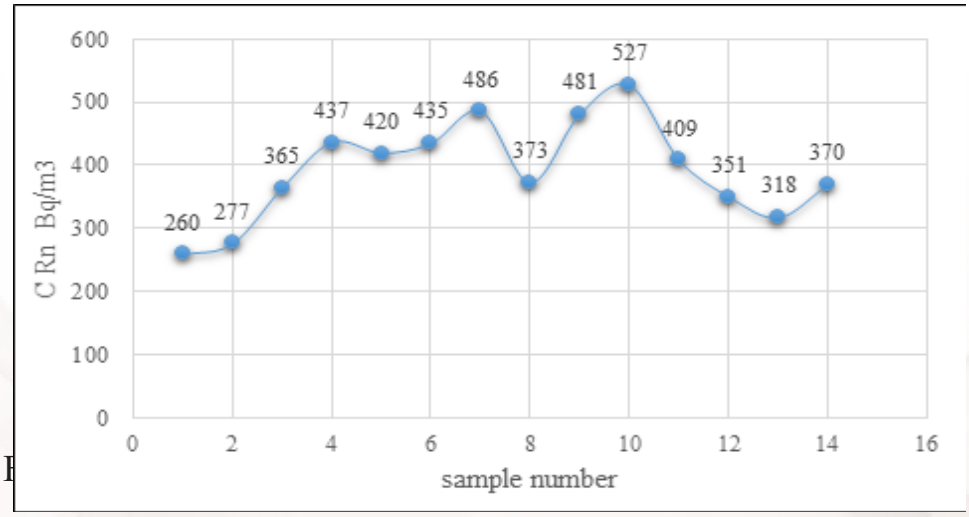
Code	Number of days	Total C_{Rn}: kBq*h/m^3	C_{Rn} ± SD Bq/m^3	H mSv.y^{-1}	WL	WLM
G15	147	1257	25 ± 356	8.981	0.038	0.002
G16	147	1554	31 ± 440	11.101	0.048	0.002
G17	147	1329	26 ± 377	9.511	0.041	0.002
G18	144	1042	24 ± 302	7.619	0.033	0.002
G19	144	1906	33 ± 552	13.926	0.060	0.003
G20	144	1282	26 ± 371	9.360	0.040	0.002



the working level (WL) and the working level month (WLM) for detected samples of first floor are shown in table 2 and figure 2, where the exposure period 144 days. The radon concentration detected in varies levels where found in range 260 ± 23 to 527 ± 32 Bq/m^3 for mean of overall floor samples were 393.50 ± 78.09 Bq/m^3, 50% of samples the radon concentration at high level from radon reference level range [14]. An annual effective dose found in varies value at range 6.559 to 13.296 mSv.y^{-1}, the overall average is 9.93 ± 1.97 it is in reference range, but 50% of samples high of ICRP recommended [16]. The working level (WL) range from 0.028 to 0.057 and working level month (WLM) range is 0.001 to 0.057 the values were higher to reference value of detriment coefficient at home and at work.

Table 2: The concentration of radon gas in the first floor

Code	Num-ber of days	Total C_{Rn}. kBq*h/ m^3	C_{Rn} ± SD Bq/ m^3	H $mSv.y^{-1}$	WL	WLM
E9	144	897	23 ± 260	6.559	0.028	0.001
E4	144	957	25 ± 277	6.988	0.030	0.001
E5	144	1263	26 ± 365	9.209	0.039	0.002
E8	144	1509	31 ± 437	11.025	0.047	0.002
E6	144	1451	29 ± 420	10.596	0.045	0.002
E3	144	1504	30 ± 435	10.975	0.047	0.002
E2	144	1678	29 ± 486	12.261	0.053	0.002
E1	144	1293	26 ± 373	9.410	0.040	0.002
E10	144	1662	29 481±	12.135	0.052	0.002
E7	144	1821	32 ± 527	13.296	0.057	0.003
E12	147	1444	29 ± 409	10.319	0.044	0.002
E14	144	1213	28 ± 351	8.855	0.038	0.002
E13	144	1100	25 ± 318	8.023	0.034	0.002
E11	144	1277	26 ± 370	9.335	0.040	0.002



The second floor samples results were shown in table 3 and figure 3, where the radon concentration (C_{Rn}), annual effective

dose (H), the working level (WL) and the working level month (WLM) detected at the exposure period 130 days. The radon concentration detected in varies levels between 334 ± 27 - 593 ± 36 Bq/m^3 and mean of (C_{Rn}) is 471.60 ± 79.62 Bq/m^3 these valueupper the WHO reference value, therefor 80% of sample had higher value for recommended range. An annual effective dose (H) range 8.426 – 14.961 $mSv.y^{-1}$ also more of it upper of recommended range 3 – 10 $mSv.y^{-1}$ [16].The working levels (WL) and working level month (WLM) were variation range 0.036 – 0.064and 0.002 – 0.003 respectively.

Table 3: The concentration of radon gas in the second floor

Code	Number of days	Total conc. kBq*h/m^3	Rn conc ± SD Bq/m^3	H $mSv.y^{-1}$	WL	WLM
S24	130	1553	35 ± 498	12.564	0.054	0.003
S22	130	1519	34 ± 487	12.286	0.053	0.002
S27	130	1167	30 ± 374	9.436	0.040	0.002
S29	130	1430	32 ± 458	11.555	0.050	0.002
S25	130	1657	32 ± 531	13.396	0.057	0.003
S30	130	1041	27 ± 334	8.426	0.036	0.002
S23	130	1258	28 ± 403	10.167	0.044	0.002
S26	130	1627	31 ± 521	13.144	0.056	0.003
S21	130	1613	36 ± 517	13.043	0.056	0.003
S28	130	1849	36 ± 593	14.961	0.064	0.003

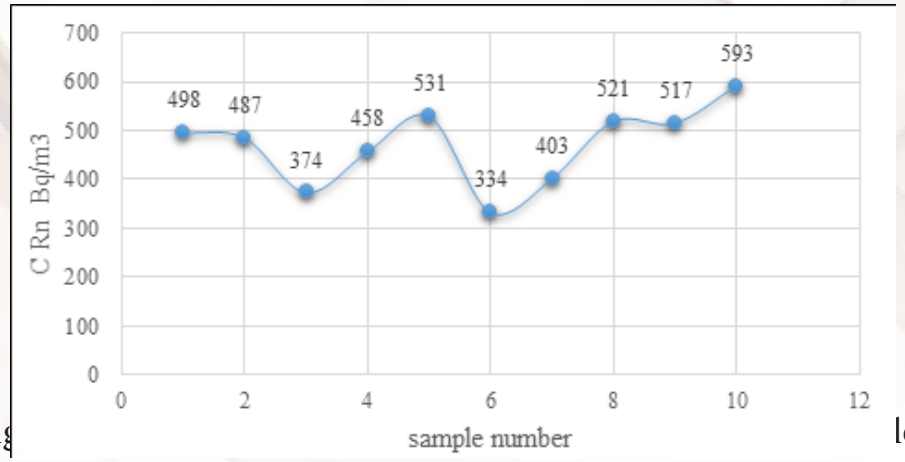


Fig les.

The relationship between radon concentration and annual effective dose obtainedinplotting shown in figure 4, there was strong positive correlation when radon concentration increases the annual effective dose increasing. From the figure 5, the strong positive correlation 1 has been obtained between annual effective dose and working level for the samples. When annual effective dose increases the working level increase too, so annual effective dose annual effective dose and working level depending on radon concentration.

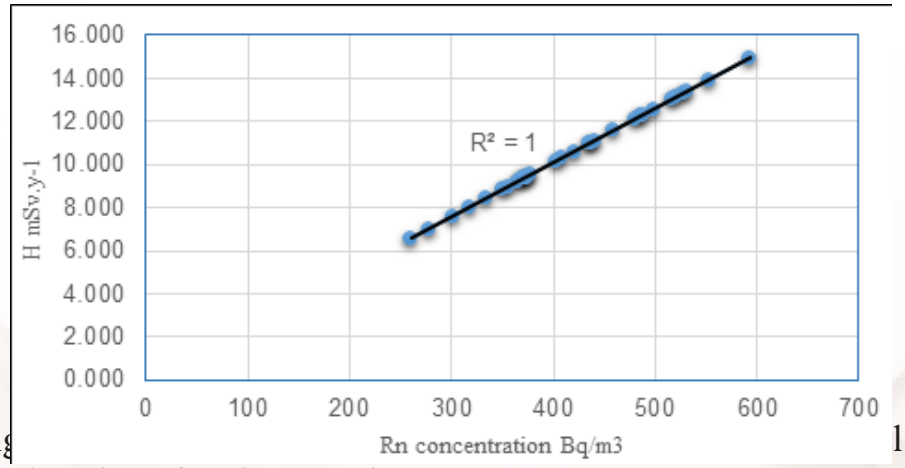
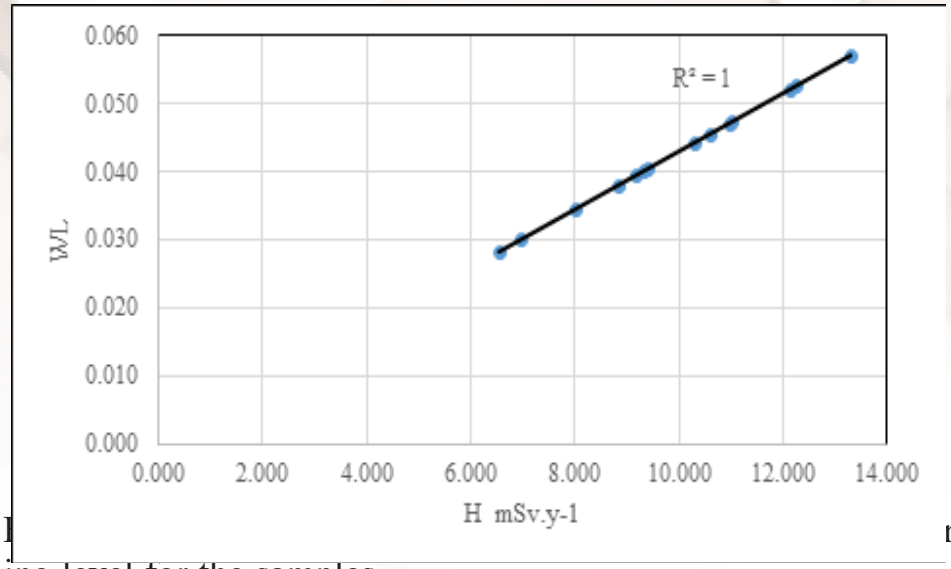


Fig l effective dose for the samples.



rking level for the samples.

Conclusions:

The results of samples of area study the level of radon concentration varied from 260 to 593 Bq/m^3 and average value around between 393.50 for first floor to 471.60 for second floor more sample are clear but some samples had risk radon concentration that may refluxes to building materials of new buildings. The radon concentration in first floor was less than in ground floor but high ratio reported in second floor samples. We found strong correlations between Rn concentration and annual effective dose and between annual effective dose and working level. **Recommendation:**Although the high radon level measured in some samples there not dangers in the workers' health, we recommend to use filters as well as ventilation.

References:

(1) Atiya, Mohammed Y., Abdel Aal, Khetam, Mahood, Balasim H., and AbdAlhussein, Mohammed. 2010. Determination of radon concentration in the center of Maysan province using CR-39 nuclear track detectors, Basra research journal, Issue 36(6) pp:15.

(2) Durrani SA, Ilic R, editors. Handbook of Radon Measurements by Etched Track Detectors: Applications in Radiation Protection, Earth Science and the Environment. World Scientific Publishing; 1997. p. 387. ISBN: 9810226667

(3) IAEA. 2013. National and Regional Surveys of Radon Concentration in Dwellings. IAEA Analytical Quality in Nuclear Applications Series No. 33, Vienna International Centre.

(4) ICRP.1993. Protection Against Radon-222 at Home and at Work. ICRP publication 65.

(5) Sahoo, B. K., Nathwani, D., Eappen, K. P., Ramachandran, T. V., Gaware, J. J., &Mayya, Y. S. (2007). Estimation of radon emanation factor in Indian building materials. Radiation Measurements, 42, 1422 - 1425.

(6) UNSCEAR. (2000). Sources and effects of ionizing radiation. Report to the general assembly, with scientific annexes appears as official records of the General Assembly, Fifty-fifth Session, Supplement No. 46 (A/55/46). New York.

(7) UNSCEAR. (2006). Effects of Ionizing Radiation. Report to the General Assembly, vol. II, annex E (United Nations publication, Sales No. E.09.IX.5).

(8) UNSCEAR (2017). Sources, effects and risks of ionizing radiation. Report to the General Assembly, with Scientific Annexes. New York.

(9) Siefert, B. ET AL., ED. (1993). Environmental carcinogens: methods of analysis and exposure measurement. Vol. 12. Indoor air. Lyon, International Agency for Research on Cancer, (IARC Scientific Publications, No. 109).

(10) EPA. (2019). Protocol for the measurement of Radon in home and workplaces.

(11) Lamonaca, F., Nastro, V., Nastro, A., &Grimaldi, D. (2014). Monitoring of indoor radon pollution. Measurement, 47, 228–233.

(12) Gupta, M., Mahur, A. K., &Verma, K. D. (2011). Monitoring of indoor radon and its progeny in dwellings of Delhi using SSNTDs. Advances in Applied Science Research, 2, 421–426.

(13) UNSCEAR. (2000). Sources and effects of ionizing radiation. Report to the general assembly, with scientific annexes; New York.

(14) WHO (2007). International Radon Project Survey on Radon Guidelines, Programmes and Activities. World Health Organization, Geneva.

(15) ICRP. (2014). Radiological Protection against Radon Exposure. ICRP Publication 126, Ann. ICRP 43(3).

(16) CRP. (1993). Protection against radon-222 at home and at work. ICRP Publication 65 Annals of the ICRP, 23(2).