I.J.S.N., VOL.7 (2) 2016: 364-369 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

MEASUREMENT OF INDOOR RADON CONCENTRATION IN SOME DWELLINGS OF ADWA, ETHIOPIA

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ABSTRACT
An indoor radon measurement was carried out in different dwellings in Adwa using Passive techniques Solid-state nuclear track detectors (LR-115 type II plastic track detectors) in a bare mode. The detectors were properly arranged in 12 houses and collected after an exposure time of 47days. The detectors were etched using 2.5N NaOH solution at 60°C for 75 minutes. The films were studied under transmitted light microscope and counted the tracks for each film. The results show that, the indoor radon concentration in the dwellings varied from 14.22 Bq m^{-3} to 161.74 Bq m^{-3} with mean value of 56.72 Bq m^{-3} and standard deviation of 40.43. The values of indoor radon concentrations in the dwellings are below the lower limits of reference level (200 Bq m^{-3}) as recommended by (ICRP, 2009) and (WHO, 2009), but 8.3% of them are higher than the reference level of 148 Bq m^{-3} as recommended by (EPA, 1987). The potential alpha energy concentration in the dwellings varied from 1.53 mWL to 17.49 mWL with mean value of 6.13 mWL and standard deviation of 4.37. All values of potential alpha energy concentration in the dwellings are lower than the recommended value of (53.33 mWL) by (UNSCEAR, 1993).The inhalation doses in the dwellings varied from 0.13mSv/Y to 1.46mSv/Y with mean value of 0.51mSv/Y and standard deviation of 0.36. In all the dwellings the inhalation dose is found less than the lower limit of the reference level (3 mSv/y) recommended by (ICRP, 1993). The mean radon concentration in the ground and first floor rooms were 59.82 $Bqm^{-3}$and 50.52 Bq m^{-3} respectively and the mean radon concentrations in living rooms, offices and stores were 27.82 Bq m^{-3}, 62.87 Bq m^{-3} and 108.39 Bq m^{-3}respectively. Risk of lung cancer related to radon is expected to be negligible in these dwellings; therefore, living in these dwellings are comparatively safe.

KEYWORD: Significant difference, t-test, One way of ANOVA, Room type, Room position, LR-type II detector, Adwa , Ethiopia.

INTRODUCTION

Radon is radioactive and noble gas element with symbol Rn and atomic number 86 which is colorless, odorless, tasteless and occurring naturally as a decay product of radium[1]. It cannot be identified without special equipment. Its most stable isotope, ^{222}Rn, has a half-life of 3.82 days. Among the densest substances that remain a gas under normal conditions is Radon[2] and it is the only gas under normal conditions that has radioactive isotopes[3].Thorium and Uranium are sources of radon and they are naturally occurring elements that are found in low concentration in soil and rock[1]. Radium is a decay product of either Uranium or Thorium and Radon is produced from the radioactive decay of the element radium. The three primordial series ^{235}U, ^{232}Th and ^{238}U are radioactive and they emit alpha-particle in their decay process[7]. The half–lives of ^{219}Rn (Actinon, 3.96 s) and ^{220}Rn (Thoron, 55.6 s) are short, and they have a low abundance relative to ^{222}Rn (Radon, 3.82 d)[22]. In general sources of radon in dwellings are, radon exhaled from the building materials and the soil/rocks below the building and inflow of radon containing air[2]. Some of the principle ways of reducing the amount of radon entering a house are increasing under floor ventilation, installing a radon sump system, improving the ventilation of the house and sealing floors and walls[3]. Radon has merit and demerit to human beings. Radon has been produced for use in radiation therapy, though currently the most part has been replaced by the man made radionuclides such as accelerators and nuclear reactors[5]. One of the basic necessity for life is clean air. Continuous supply of air is needed for human beings. The quality of air inside homes, schools, public buildings, offices, health care facilities or other private and public buildings where people spend a large part of their life is an essential determinant of healthy life and people's comfort. Dangerous substances like radon released from such buildings, construction materials, water and soil, lead to a wide-range of health problems[10]. Radon is existing in air in very small concentrations and moves in and out of our lungs with the rest of the air in the normal process of breathing. When radon in the air decays into its daughter products, it forms atoms of solid elements which are negatively charged. These negatively charged particles attach themselves to the small dust particles in the air to form a radioactive aerosol[3]. When we breathe these particles into our lungs, they are not exhaled rather they stick to the airway of the lung[1]. They expose the lung tissue, as they are still radioactive. The polonium-214 and polonium-218 emit highly energetic alpha radiation causing damage to the DNA of cells airway of lungs[19]. The damaged cells increase the risk of developing lung cancer[3,20]. At any level of exposure to radon, DNA damage can take place; even a single alpha particle can cause damage to a cell[20]. Radon is the second cause of lung cancer after smoking in many countries[18], however, it is the first cause of lung cancer for non-smokers [5]. Generally lung cancer risk from radon depends mostly on the level of radon, the duration of exposure and the individuals smoking habits[18]. Bearing in mind this risk the aims of the present study are to determine indoor radon concentration, potential alpha energy concentration (PAEC), inhalation dose (D_{in}) and check statistical significance difference in the concentration of radon on parameters depend on room position and room type in the dwellings of Adwa , Ethiopia.

MATERIALS & METHODS

From the different methods used in many researches, in this present research work experimental method is setup to measure indoor radon concentration in some dwellings of Adwa, Ethiopia. Passive techniques Solid-state nuclear track detectors (LR-115 type II plastic track detectors) in a bare mode were used. The LR-115 type II plastic track detector film, consists of a layer of cellulose nitrate powerfully red colored, and coated on an inert polyester base 100μm thick used as a supporting material[2]. So, one side of the film surface is sensitive and the other side is not etchable [7]. Thickness of 12μm of the layer is good for alpha particles in LR-115 type II film. These LR-115 films were cut into 12 smaller sizes of nearly 3x3 cm^2 each by scissor. These small size 12 films of LR-115 were attached on a thick paper, acts as a supporting material each separately and each detector is coded with special number and letter. After the detectors were prepared, these 12 thick papers which hold the 12 detectors each were suspended inside 12 different houses at a height of about 2 meters from floor and about 1m below the ceiling of the room[1,5]. The detectors were exposed for 47 days. When a charged particle like alpha slows down and stops in a solid, the energy that it deposits along its track can cause permanent damage in the material[17]. It is difficult to observe the direct evidence of this local damage, even under careful microscopic. However, the presence of the damaged track can be visible through chemical etching of the material surface of the detector[3]. After preparing the etching solution (that is, 2.5N NaOH), it is kept for some hours until it becomes homogeneous. During this time the detectors were removed from the thick paper by cutting the plastic around the detectors carefully with a sharp scissor, taking care of keeping the surface of the detectors clean from marks. To etch the detectors, 12 beakers were used having 2.5N NaOH solution.The beakers were then placed in a constant temperature bath after having poured the solution and each detector is placed into a beaker. The detectors were etched with 2.5N NaOH solution at 60ºC for 75 minutes. During the entire process of etching the temperature was kept at (60 ± 1ºC). After 75 minutes, the detectors were removed and washed with distilled water, to remove the etching deposit. After appropriate chemical etching, visible tracks formed in these cellulose nitrate films (LR-115 Type II Plastic Track Detectors)[21]. After drying (Fig 1), the detectors were ready for counting using the transmitted polarized microscope (James Swift)(Fig 2).

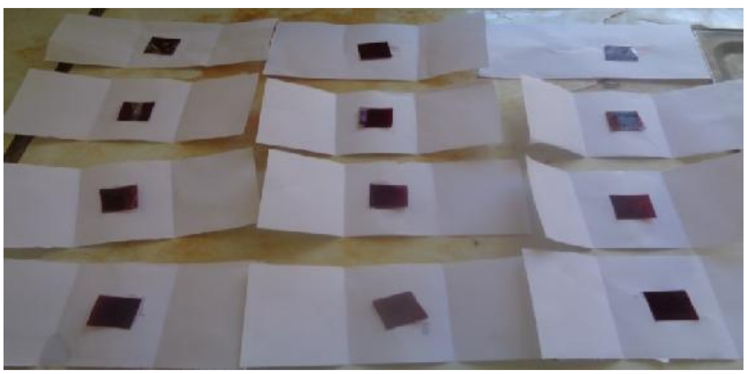

FIGURE 1: Drying LR-115 detectors after chemical etching

For measuring radon concentration that is connected with the track density, polarized light microscope (Fig 2) is used with a magnification of 400 times (10 x eye piece and 40 x objective).

FIGURE 2: Polarized light Microscope

Before counting the tracks, the researcher determined the area of the fields of view and keeps it constant throughout the counting. The average length and width of one field of view (FoV) was found 0.75cm and 0.75cm respectively. Therefore the area of one field of view (FoV) = 0.75cm x 0.75cm = 0.5625cm^2. Finally the total area of all the 16 field of views was given byTFoV= no of views xFoV TFoV=16x0.5625cm^2=9cm^2

The average track density of each detector was calculated as follow[3]:

$$\rho = \frac{T}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where (ρ) is the track density in track /cm^2, (T) is total number of tracks counted in all fields of view and (A) is total area of fields of view

The standard deviation was calculated by the formula given below[1].

$$\delta = \sqrt{\sum \frac{(x-\bar{x})}{n} 2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where x, $\bar{x}$ and n are the individual result, the mean result and the number of samples respectively.

The Potential Alpha Energy Concentration (PAEC) in terms of (mWL) units was obtained using the formula[1,4,5,16]:

$$\mathrm{Cp(mWL)} = \frac{\rho}{kt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where (ρ) is the track density (track /cm^2), (k) is the calibration factor which is 1.61 track.cm^{-2}/ Bq.d.m^{-3}, and (t) is the exposure time which is equal to (47) days

Radon concentration (C_{Rn}) in the dwellings was calculated as follows [1,5,15,16]:

$$C_{Rn}\ (\mathrm{Bq.\ m^{-3}}) = 3.7\ C_p / F \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where (F) is the equilibrium factor which is equal to (0.4 and C_{Rn} is the activity concentration of radon in Bq.m^{-3}.

The inhalationdose (D_{in}) in terms of (mSv/y) units was obtained using the formula [16]:

$$D_{in}\ (\mathrm{mSv/y}) = nC_{Rn} = 0.009C_{Rn} \ldots\ldots\ldots\ldots\ldots (5)$$

Where n is a constant which equal to 0.009 (mSv.m^3/Bq.y).

Finally the statistical significance difference was tested using t-test for independent sample and One Way of ANOVA in SPSS version 20 at p value 0.05.

RESULTS & DISCUSSION

As shown in Table 1 the indoor radon concentration in the dwellings varied from 14.22 Bq m^{-3} to 161.74Bq m^{-3} with mean value of 56.72 Bq m^{-3} and standard deviation of 40.43.This mean value is lower than the level reported in previous studies in other parts of Ethiopia[1,5,16] and in other countries[3, 6, 14, 15, 23]. But it is higher than the concentration level reported in other countries[8,17]. International Commission on Radiological Protection (ICRP, 1993) recommended the action levels as 200-600 Bq m-3 for dwellings[13] and World Health organization (WHO, 2009)[20] recommend radon concentration should be less than 100 Bq m^{-3}.

TABLE 1: Radon concentration, potential alpha energy concentration, and track density and inhalation dose in some dwellings of Adwa, Ethiopia

House code	Room position	Room type	Location	Tracks/cm^2	C_P(mWL)	C_{Rn}(Bq/m^3)	D_{in}(mSv/Y)
1	Ground	Living room	Around Adwa Hospital	327.22	4.32	40.00	0.36
2	Ground	Living room	Gezagowo	232.67	3.07	28.44	0.26
3	Ground	Living room	Digadig	116.33	1.53	14.22	0.13
4	first floor	Living room	Around Dembosco	178.56	2.36	21.83	0.20
5	Ground	Store	Atsede Mariam clinic	1323.11	17.49	161.74	1.46
6	Ground	Living room	Snwo	383.67	5.07	46.90	0.42
7	first floor	Office	Adwa Market	454.56	6.01	55.57	0.50
8	Ground	Office	Damicheal	532.67	7.04	65.11	0.59
9	first floor	Office	Adwa CTE	555.78	7.34	67.94	0.61
10	Ground	Store	Adi-Awun	872.33	11.53	106.64	0.96
11	Ground	Living room	Hangary	126.89	1.68	15.51	0.13
12	first floor	Store	Adimahleka	464.33	6.14	56.76	0.51

The mean indoor radon level (56.72 Bq m^{-3}) found in Adwa is below the lower limits of reference level (200 Bq m^{-3}) as recommended by the (ICRP, 2009)[12] and (WHO, 2009)[20]. This value is also less than 148 Bq m^{-3}) as recommended by (EPA, 1987)[24].The mean indoor radon concentration (56.72 Bq m^{-3}) and the values of indoor radon concentrations in the individual dwellings of Adwa under study are below the safe limit as recommended by (ICRP,1993) and (EPA, 1987) except in one dwelling, code 5. The value of indoor radon level of code 5(store room) is 161.74 Bq m^{-3}, which is above the safe limit recommended by (EPA, 1987), this is may be due to store rooms are closed most of the time and resulted in poor ventilation. The variation of indoor Radon concentrations in the dwellings of Adwa may be due to many factors such as house type, design and construction, local geology, soil permeability, ventilation condition *etc*.[3] and indoor radon concentration can therefore vary significantly even between neighboring homes[9]. The potential alpha energy concentration in the dwellings of Adwa varied from 1.53 mWL to 17.49 mWL with mean of 6.13 mWL and standard deviation of 4.3. This mean value is lower than the potential alpha energy concentration reported in previous studies in other parts of Ethiopia [1, 5, 16] and in other countries[15]. But it is higher than the potential alpha energy concentration reported in other countries[17]. All values of potential alpha energy concentration in the indoor dwellings of Adwa are lower than the recommended value of (53.33 mWL) by (UNSCEAR, 1993)[21]. The inhalation doses in the dwellings of Adwa under study varied from 0.13mSv/Y to 1.46mSv/Y with mean value of 0.51mSv/Y and standard deviation of 0.36. This mean value is lower than the inhalation dose reported in previous studies in other parts of Ethiopia [1,5,16] and in other countries[6,15]. In all the dwellings surveyed in Adwa the inhalation dose is found less than the lower limit of the action level (3 mSv/y) recommended by International Commission on Radiological Protection (ICRP,1993)[13].

TABLE 2: The comparison of mean C_{Rn}, C_P and D_{in} in indoor air samples with different studies in different countries

Study number	Country	Location	Techniques used	Mean C_{Rn}(Bqm^{-3})	Mean C_P(mWL)	Mean D_{in}(mSv/y)	Reference
1	Ethiopia	Adwa	LR-115	56.72	6.13	0.51	Present study
2	Ethiopia	Motta	LR-115	82.05	8.80	0.73	[5]
3	Ethiopia	Lalibela	LR-115	140.64	12.73	3.71	[1]
4	Ethiopia	Debre Markos	LR-115	217.01	23.46	1.95	[16]
5	Nepal	Kathmandu valley	LR-115	80.00	-	-	[23]
6	Iraq	Thi-Qar Governorate	LR-115	153.73	16.62	3.87	[15]
7	Northern & Central Iraq	Iraq	LR-115	59.93	-	1.425	[6]
8	Saudi Arabia	Zulfy City	CR-39	74.67	-	-	[3]
9	India	Haryana	LR-115	13.00	1.40	-	[17]
10	India	Rampur	LR-115	62.36	-	-	[14]
11	Vietnam	NinhThuan	LR-115	10.00	-	-	[8]

As shown in the Table 2, the mean radon concentration from the present study is lower than those reported in the other studies conducted at national levels [1,5,16] and in other countries [3, 6, 14, 15, 23]. But it is higher than the radon level reported in other countries[21,22]. There may be a number of reasons such as the dwellings ventilation system was remarkably may not be good enough and building materials, which are usually considered as important income pathways of radon in buildings[3].

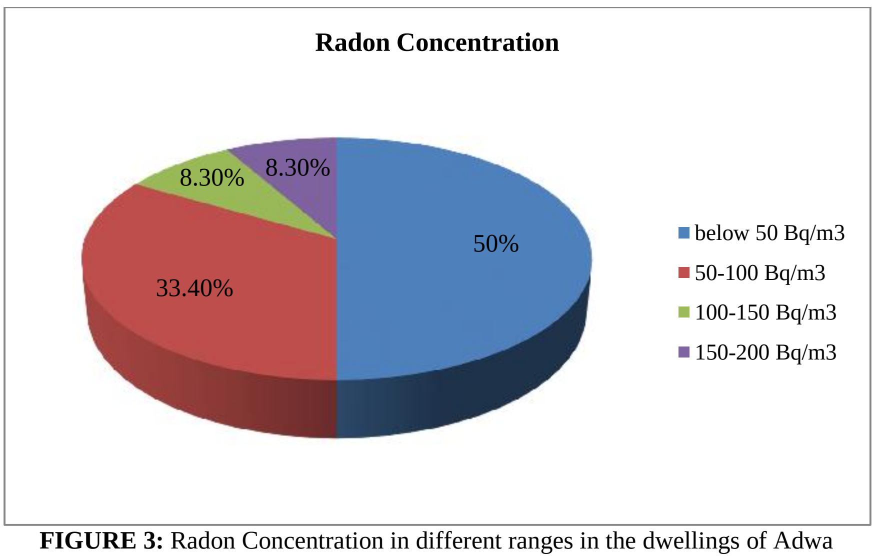

FIGURE 3: Radon Concentration in different ranges in the dwellings of Adwa

As it can be seen in Figure 3, about 50% of the dwellings have concentrations below 50 Bqm^{-3}. This low concentration might be due to the fact that these dwellings were well ventilated. On the other hand, about 33.4% of the dwellings have concentrations between 50 Bqm^{-3} and 100 Bqm^{-3}, 8.3% dwellings have concentrations of between 100 Bqm^{-3} and 150 Bqm^{-3} and the remaining 8.3% dwellings have concentrations of between 150 Bqm^{-3} and 200 Bqm^{-3}.This high concentrations might be due to poor ventilation system of the dwellings.

From Table 3, the mean radon concentration of ground and first floor room are 59.82 Bq/m^3 and 50.52 Bq/m^3

respectively. At the column 'Sig. (2-tailed)', the probability value (*ρ)* is 0.737 which is greater than the significant level of 0.05. This tells that there is no statistically significant difference between the concentration of radon measured from ground and first floor dwellings. Therefore radon is independent of height.

TABLE 3: Independent samples t-test for radon concentration under category of room position

Type of Concentration	Room Position	N	Mean	Std. Deviation	Std. Error Mean	Df	T	Sig.(2-tailed)
Radon	Ground	8	59.82	50.98	18.02	10	0.345	0.737
	Floor 1	4	50.52	19.92	9.96			

As shown in Table 4, the mean radon concentrations all types of rooms are 27.82 Bq/m^3, 62.87 Bq/m^3 and 108.39 Bq/m^3 for living rooms, office rooms and store rooms respectively .Out of these, the store rooms have the highest radon concentration while the office rooms the lower radon concentration and living rooms the lowest concentration, while living rooms have the lowest concentration. The mean of radon concentration in Adwa store rooms is higher and the mean radon concentration in Adwa office rooms is lower than the previous study reported in other country[3]. In general, the one way ANOVA results show that there is a statistical significant difference among the different rooms of all types since p-values are high, that is, probability value (*ρ=0.007)* is less than significant level (P=0.05) as a result concentration of radon in the different rooms are significantly different, and therefore radon depends on rooms type.

Table 4 One way of ANOVA for Concentration of Radon under category of Room type

Room Type	N	Mean	Std. Deviation	F	Sig.
Living Room	6	27.82	13.31	9.114	0.007
Office	3	62.87	6.48		
Store	3	108.39	52.51		

As shown in Table 5 in comparing between two types of rooms, one can see that the two types of rooms (living room and office room) do *not* differ statistically significantly from each other (Sig. = 0.098, *i.e. ρ* >0.05), and the other two types of rooms (office room and store room) do not differ statistically significantly from each other (Sig. = 0.068, *i.e. ρ* >0.05), but the two types of rooms (living room and store room) *do* differ statistically significantly from each other (Sig. = 0.002, *i.e. ρ* <0.05). So, it is possible to conclude that Store rooms have higher concentration than other rooms because of ventilation effect, which is in agreement with other study [3].

TABLE 5: LSD on radon concentration on room type

Room type (I)	Room types (J)	Mean Difference (I-J)	Sig.
Living room	Office	-35.05609	.098
	Store	-80.56155*	.002
Office	living room	35.05609	.098
	Store	-45.50546	.068
Store	living room	80.56155*	.002
	Office	45.50546	.068

CONCLUSION & RECOMMENDATIONS

The overall mean value of radon concentration in the present study is found to be below the lower limits of reference levels (200 Bq m^{-3}) and (100Bq m^{-3}) as recommended by the (ICRP, 2009)[12] and (WHO, 2009)[20] respectively. However, 8.3% of them are higher than the action level of 148 Bq m^{-3} as recommended by (EPA, 1987). The overall mean of potential alpha energy concentration of the present study is lower than the recommended value of (53.33 mWL) by (UNSCEAR, 1993)[19]. Likewise the overall mean of inhalation dose in the present study is less than the lower limit of the action level (3 mSv/y) recommended by (ICRP, 1993)[13].There is no statistical significance difference on mean of radon concentration on room position, that is, radon concentration is independent of height. On the other hand, there is statistical significance difference on mean of radon concentration on room type, that is, radon concentration depends on room type. Risk of lung cancer related to radon is expected to be negligible in these dwellings; therefore, living in these dwellings is comparatively safe.

ACKNOWLEDGMENTS

The Authors thanks to Mekelle University and to the peoples living in the randomly selected dwellings of Adwa under study who allowed to fix the LR-115 Type II detectors and helped in distributing and collecting these detectors.

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