Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.7, No.7, 2017

Indoor Radon Concentration and its Associated Health Effect in the Dwellings of Fiche Selale North Shewa, Ethiopia

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Abstract
Radon is a natural radioactive gas without odor, color or taste. It founds in all rocks, soil, concrete and bricks. The measurements of ^{222}Rn concentration in a total of 13 different dwellings in Fiche Selale were investigated. The concentrations were measured by alpha spectroscopy detection technique with Corentium digital radon detector. It was found that the overall average indoor radon concentration in the dwelling varies from 45.88 ***Bq/m^3*** to 266.59 ***Bq/m^3***, which is above the recommended action level. The average annual effective inhalation dose varied from 0.62 ***mSv/y*** to 2.4 ***mSv/y.*** The mean excess lung cancer risk estimated by this work was found to range from 0.87 % to 5.71 % within average value of 2.76%. The average of Excess Lifetime Cancer Risk (ELCR) is greater than with the estimated risk of 1.3 % (13 deaths in 1000 peoples) due to a radon exposure of 148 Bqm^{-3} which is the action level of Environmental protection agency (EPA).
Keywords: indoor radon, inhalation dose, life fatality risk, Corentium radon detector, working level

1. Introduction

Radon is a noble gas produced by the radioactive decay of radium, found in uranium ores, phosphate rock, and a number of common minerals. It is an invisible, odorless, and tasteless gas that seeps up through the ground and diffuses into the air. It undergoes radioactive decay producing a series of short-lived progeny, often called daughters that can emit alpha, beta, or gamma particles and are electrically charged, readily attaching to air-borne particles. The primary source of exposure to radon is indoor or household air, because many houses and buildings have been constructed right on top of radon emitting rocks. Radon daughters are often attached to dust, and we are exposed to them primarily through breathing. In indoor locations such as homes, schools, or office buildings levels of radon and daughters are generally higher than outdoor levels. Cracks in the foundation or basement of our home may allow increased amounts of radon to move into [1, 2, and 3].

The radiation released during the process of decay passes into lung tissue and causes lung damage. There is very limited information on whether radon gas can penetrate the skin, but some radon may be able to pass through the skin when you bathe in water containing radon. Long-term exposure to radon and radon daughters in air increases the chances of getting lung cancer. When exposures are high, non-cancer diseases such as thickening of certain tissues of the lungs may occur. This usually occurs within a few days or weeks after exposure to radon (4, 5, and 6).

2. Description of the study area

Fiche is a town in central Ethiopia. It is the administrative centre of the Semien Shewa Zone of Oromiya Region and separate woreda. It is located about three km from the main Addis Ababa-Debre Markos road, Fiche has a latitude and longitude of 9°48′N latitude and 38°44′Elongitude and an elevation between 2,738 and 2,782 meters above sea level. The 2007 national census reported a total population for Fiche of 27,493, of whom 12,933 were men and 14,560 were women.

3. Materials and Methods

Experimental method for radon detection and measurements are based on alpha particle counting of radon. Alpha spectroscopy detection method with the help of Corentium digital radon detector was used for the measurements of radon in the dwellings of Fiche Selale north Shewa Ethiopia. There are 13 dwellings were selected for the measurements of indoor radon concentration. The dwellings were selected randomly some dwellings were ventilated and others were unventilated.
The effective exposure time is calculated as:

$$T_e = [T - \lambda_{Rn}{}^{-1}(1 - e^{-\lambda_{Rn}T})] \quad (1)$$

T- is the actual exposure time, λ_{Rn} is the decay constant for radon gas.
The inhalation dose was calculated in (mSv.y−1) using the relation:

$$D_{in}(Sv/y) = nC_{Rn} = 0.009C_{Rn} \quad (2)$$ [1, 2]

Where n is a constant which equal to 0.009 (mSv.m3/Bq.y). Radon concentration in the working level:

$$C_{Rn}(Bqm^{-3}) = \frac{3700xWLR}{F_R} \quad \text{.....(3)}$$

Where F_{Rn} is the equilibrium factor of radon which is 0.4 [6]. The calculations will be made using the conversion factors given elsewhere.

The excess lifetime cancer risk (ELCR) due to radon is:

$$ELCR = E_R \times T \times F_R \quad \text{.....(4)}$$

Where E_R - Exposure of radon WLM/Y, T – Average life time expectancy of the country (62.25 for Ethiopia), F_R - Risk coefficient factor for exposure to radon in equilibrium and its progeny and based on ICRP $F_R = 5 \times 10^{-4}$ per WLM = 0.0357 Bq/m^3 , alpha index: Several indexes dealing with the assessment of the excess alpha-radiation due to radon inhalation originating from building materials (called “alpha indexes” or “internal indexes”) have been developed [7]. The alpha indexes were determined using the following formula:

$$I_\alpha = \frac{C_{Ra}}{200kg^{-1}} \quad \text{.....(5)}$$

4. Result and Discussion

In the present study, we have measured the values of radon levels in the indoor environment of some dwellings of Fiche Selale north Shewa Ethiopia. Annual effective dose has also been calculated for the occupants of these dwellings. It has been observed that the long term radon concentration varied from 47.36 **Bq/m^3** to 292.67 **Bq/m^3** with an average value of 146.58 **Bq/m^3** and the short term radon concentration is varied from 44.4 **Bq/m^3** to 240.5 Bq/**m^3** with an average value of 135.88 **Bq/m^3**.

Sample No.	**Short term average of C_{Rn}(Pci/L)**	**Inhalation dose D_{in} (mSv/y)**	**Alpha index I_α**	**Excess Lifetime Cancer Risk (ELCR) %**	**working level of radon (WLR) (Bq/m^{3}y)**
1	73.26	0.66	0.37	1.43	29.30
2	124.69	1.12	0.62	2.43	49.88
3	226.81	2.04	1.13	4.43	90.72
4	169.83	1.53	0.85	3.32	67.93
5	61.05	0.55	0.31	1.19	24.42
6	89.91	0.81	0.45	1.76	35.96
7	51.43	0.46	0.26	1.00	20.57
8	131.72	1.19	0.66	2.57	52.69
9	47.36	0.43	0.24	0.92	18.94
10	292.67	2.63	1.46	5.71	117.07
11	219.78	1.98	1.10	4.29	87.91
12	183.89	1.66	0.92	3.59	73.56
13	233.1	2.10	1.17	4.55	93.24
Average	146.58	1.32	0.73	2.86	58.63

Table 1:- Short term radon concentration and its internal dose, excess lifetime cancer risk, working level and alpha index.

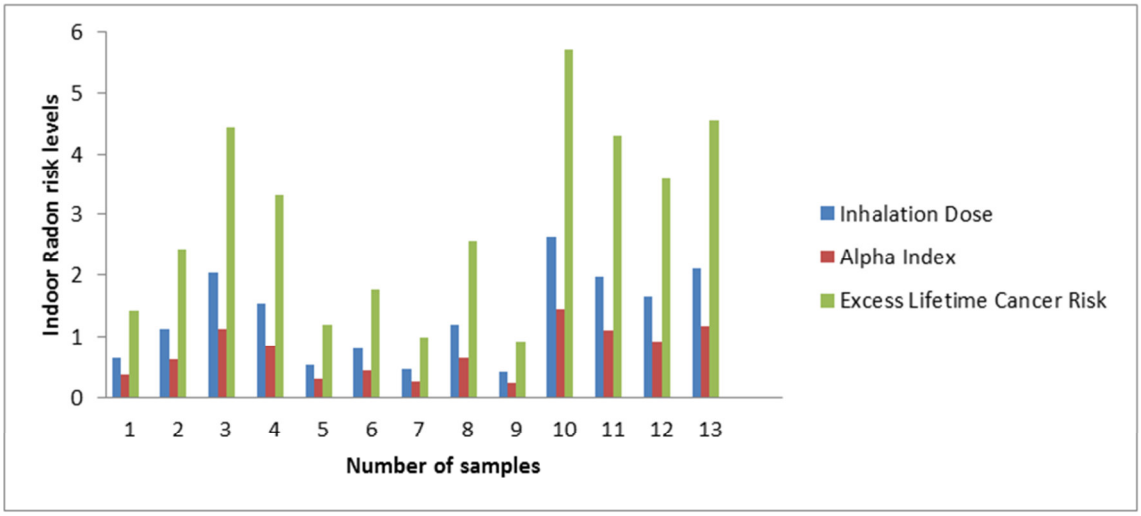

Figure 2:- Description of the short term average radon risk level in different parameters for each sample.

The overall average indoor radon concentration is varied from 45.88 **Bq/m^3** to 266.59 **Bq/m^3**. The variation of the indoor radon concentration is may be due to the environmental condition, soil nature, nature of construction materials as well as ventilation condition of the houses.

Sample No.	**Long term average of C_{Rn}(Bq/m^3)**	**Inhalation dose D_{in} (mSv/y)**	**Alpha index I_α**	**Excess Lifetime Cancer Risk (ELCR) %**	**working level of radon (WLR) (Bq/m^{3}y)**
1	73.26	0.66	0.37	1.43	29.30
2	124.69	1.12	0.62	2.43	49.88
3	199.8	1.80	1.00	3.90	79.92
4	144.3	1.30	0.72	2.82	57.72
5	59.2	0.53	0.30	1.16	23.68
6	77.7	0.70	0.39	1.52	31.08
7	44.4	0.40	0.22	0.87	17.76
8	129.5	1.17	0.65	2.53	51.80
9	47.36	0.43	0.24	0.92	18.94
10	240.5	2.16	1.20	4.69	96.20
11	219.78	1.98	1.10	4.29	87.91
12	183.89	1.66	0.92	3.59	73.56
13	222	2.00	1.11	4.33	88.80
Average	135.88	1.22	0.68	2.65	54.35

Table 1:- Short term radon concentration and its internal dose, excess lifetime cancer risk, working level and alpha index.

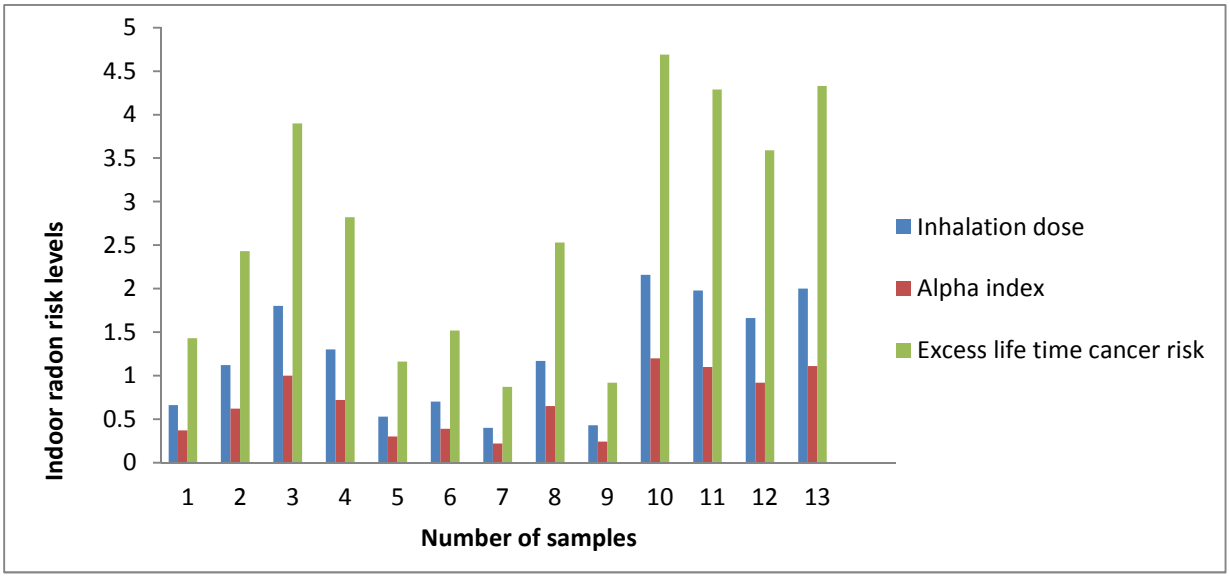

Figure 2:- Description of the long term average radon risk level in different parameters for each sample.

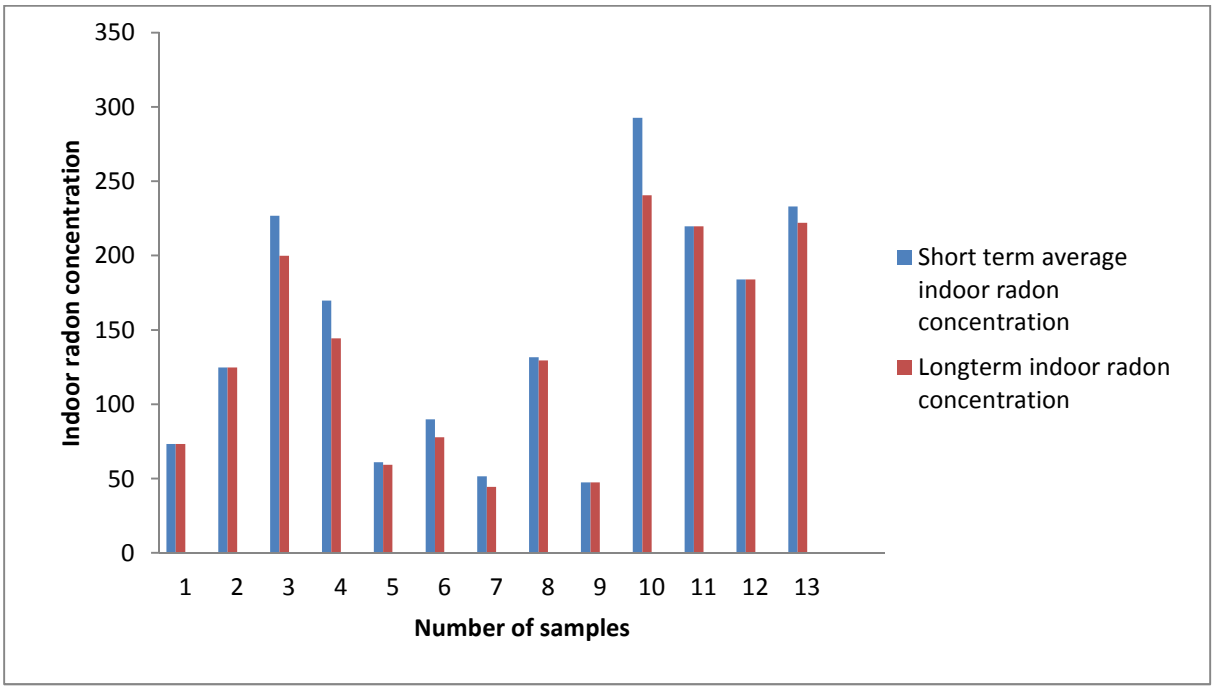

Figure 2:- Comparisons of long and short term indoor average radon concentration.

The maximum values were found in guest rooms and minimum values were found in living rooms. For the inhalation part, we have known that the dissolved radon is a source of indoor radon, and its contribution would depend on the radon concentration, usage rate, the volume of the indoor environment and the air exchange rate. The average value of inhalation dose is 1.32 **mSv/y** and 1.22 **mSv/y** in long term and short term indoor radon concentration respectively, with in a total average value of 1.27 **mSv/y**. The average annual effective dose varied from 0.62 **mSv/y** to 2.4 **mSv/y.** The mean excess lung cancer risk estimated by this work was found to range from 0.87 % to 5.71 % within average value of 2.76%. The average of Excess Lifetime Cancer Risk (*ELCR*) is greater than with the estimated risk of 1.3% (13 deaths in 1000 peoples) due to a radon exposure of 148 Bqm^{-3} which is the action level of Environmental protection agency (EPA) [5]. The study area needs more investigation on radon concentration in soil, water and building materials. The result indicates that the place needs caution in order to minimize the concentration.

Conclusion

From the result we observed that Fiche Selale north Shewa, Ethiopia has relatively higher indoor radon levels as compared to the other Ethiopian provinces as measured by other research groups [6, 7, 12]. The overall

arithmetic mean of the present survey 141.23 Bq/$\mathbf{m^3}$ is much higher than the typical global indoor radon level, (40 Bqm^{-3}). The annual effective inhalation dose received by the residents in the study area is near to the limit of the recommended action level (3–10 mSv). The soil nature, nature of construction materials, and ventilation conditions of the dwellings played an important role in order to decide the values of indoor radon concentration and effective dose. The average of Excess Lifetime Cancer Risk (ELCR) is greater than the estimated risk of 1.3 % (13 deaths in 1000 peoples), due to a radon exposure of 148 Bqm^{-3} which is the action level of Environmental protection agency of America (EPA). This implies that, it can pose significant threat to the population.

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