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RISK ASSESSMENTS OF RADIUM CONTENT AND RADON EXHALATION RATES IN SOIL SAMPLES OF SHIRE INDASLASSIE AREA, ETHIOPIA

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ABSTRACT
Everyone is exposed to radon because it occurs everywhere with varying concentrations. Radon and its progeny are well established as lung carcinogenic. Radon is a gas and decay product of radium. Radium mainly enters the body through the food chain. Soil is the main source of radium. With the motivation of the health hazards the present work has been carried out. "Sealed Can Technique" using LR-115 type II plastic track detector has been used to measure the effective radium content, radon concentration and radon exhalation rates in soil samples are collected from Shire Indaslassie town and Tseadaemba village, Tigray region, Northern, Ethiopia by grab sampling method from a depth of 50 cm. The values of effective radium content are found to vary from 7.73 to 125.4 $Bq.kg^{-1}$ with a mean value of 72.24 $Bq.kg^{-1}$ and standard deviation of 42.26 $Bq.kg^{-1}$. The mass exhalation rates of radon vary from 2.04×10^{-6} to 33.1×10^{-6} $Bq.kg^{-1}.d^{-1}$ with a mean value of 19.07×10^{-6} $Bq.kg^{-1}.d^{-1}$ and standard deviation of 11.2 $Bq.kg^{-1}.d^{-1}$. The surface exhalation rates of radon have been found to vary from 5.3×10^{-5} to 85.97×10^{-5} $Bq.m^{-2}.d^{-1}$ with a mean value of 49.52×10^{-5} $Bq.m^{-2}.d^{-1}$ and standard deviation of 29.1×10^{-5} $Bq.m^{-2}.d^{-1}$. While, radon concentration has been found to vary from 7.7 to 124 .86 $Bq.m^{-3}$ with a mean value of 42.26 $Bq.m^{-3}$ and standard deviation of 40.6 $Bq.m^{-3}$. Radon exhalation study is important for understanding the relative contribution of the material to the total radon concentration found inside the dwellings. The values of radium content and radon exhalation rates are found below the safe limit as recommended by Organization for Economic Corporation and Development (OECD).

Keywords: Radium content, Radon exhalation rates, LR-115 detector, Can technique Plastic cylindrical cans, polarized light optical microscope.

Introduction

The largest contributor of ionizing radiation to the population is natural radioactivity. It is present everywhere within us and surrounding environment in varying concentrations. The natural radiation sources such as granite, soils, and sand, water and food items contribute about 80 % radiation dose received by human being [1, 2, and 3]. Soil is the main sources of continuous radiation exposure to humans. It acts as a medium of migration for transfer of radio nuclide in to our environment. Hence the soil is the basic indicator of radiological contamination in the environment [4]. The naturally occurring radionuclide's present in the soil are mainly ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. This radionuclide's causes radiological hazard externally due to the gamma ray emission and internally due to inhalation of radon and its progeny [4, 5]. When human exposure to natural radiation source is considered, radon and its short lived decay products in the environment are the most important contributors [1].

Radium (^{226}Ra) and radon (^{222}Rn) mainly come from naturally occurring uranium (^{238}U), which is present in all types of rocks, building materials and soils in parts per million (ppm). Radium, being a member of uranium radioactive series, is present everywhere in the earth's crust therefore; radon, which is the daughter product of radium, is also found everywhere in varying levels. Radium mainly enters the body through the food chain and being chemically similar to calcium, tends to follow it in metabolic processes and becomes concentrated in bones. The alpha particles given off by radium and radon bombard the bone marrow and destroy tissues that produce red blood cells. It may cause bone cancer. The radium content of a sample also contributes to the level of environmental radon as radon is produced from ^{226}Ra through alpha decay [5].

Higher values of ^{226}Ra in soil contribute significantly to the enhancement of indoor radon. The main contributors to indoor radon concentrations are soil gas emanating from the ground beneath a dwelling and the materials from which the dwelling is constructed [7].

The measurement of radium content and radon exhalation rate in soil environment is important to take care of the inhalation indoor radon dose to the general population of the region. The studies also needed to understand the Radon-222 and its progeny concentration are dependence to what factor of parameters such as humidity, temperature, characteristics of soil and others [6]. In recent years, substantial attention has been paid to natural radon, particularly to the problems of exposure to radon and its progeny in soils, buildings and dwellings [6, 17]

DESCRIPTION OF THE STUDY AREA

Shire Indasselasie is the zone level administrative region of north western Tigray, Northern Ethiopia. It is located at the northern tip of Ethiopia. Northwestern Tigray zone has seven districts: Medebay Zana district, Tahtay Koraro, district Shire Indasilassie, Asgede Tsimbla, Tselemti district, Laelay Adyabo and Tahtay Adyabo. Shire Indasilassie (Town district) and Tahtay Koraro (rural district) are the two districts of North Western Zone Administration. Shire Indaslassie is located in $14^0 6'$ north latitude and $38^0 17'$ east longitude. Whereas, Tahtay Koraro district lies in $14^0 13'$ north latitude and $38^0 21'$ east longitude. Where Tseadaemba village is part of Tahtay Koraro district. Based on the 2007 National census conducted by the Ethiopian Central Statistical Agency (ECSA), the town has a total population of 47,284, of whom 21,867 are men and 25,417 women. The Indaslassie area usually called as Shire is a mineral reach place.

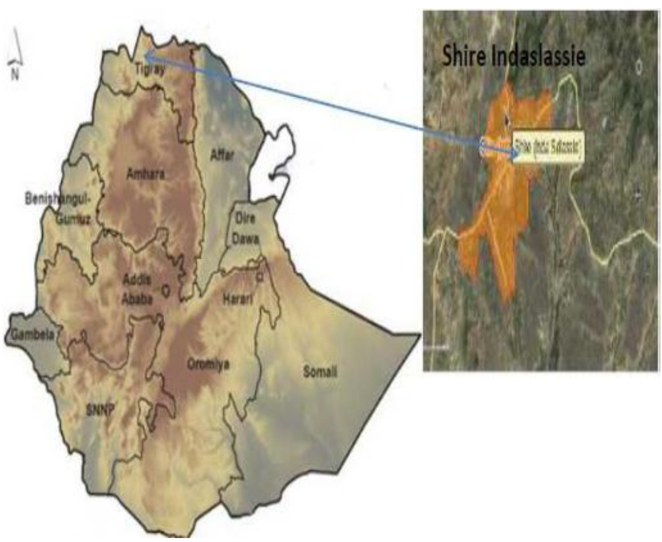

***Figure 1**: Geological location of Shire Indaslassie, Ethiopia*

This place is a new area and there is no study had been done here. Besides, there result of radium content, radon concentration and radon exhalation rates measured by using SSNTD, this study will be useful for further study in the area.

MATERIALS AND METHODS

For the measurements of radium content and radon exhalation rates from soil samples "sealed can technique" fitted with solid state nuclear track detector has been used [2, 4, 6, 17, 18]. In our experiment thirteen soil samples were collected from different places of the study area of Shire Indaslassie area in Northern Ethiopia by grab sampling method. The soil sample was collected by employing a template method from an auger hole at a depth of about 0.5 meters from the ground so as to get the natural soil. After collection, samples were dried in an oven at about 110 ^{0}C for 3 hours in order to remove the moisture content completely subsequently; each soil sample was crushed in to fine powder by using Mortar and Pestle. Fine quality of the sample was obtained using scientific sieve of 200 micron-mesh size. About 100 gm of each sample was packed and sealed in an airtight leak proof plastic can of size 10 cm in height and 7 cm in diameter, which was closed for a period of about three week in order to get equilibrium between radium and radon progenies.

After that, 2 × 2 cm size of LR-115 type II plastic track detector fitted on the top inner side of the cane as shown in the fig. 2.

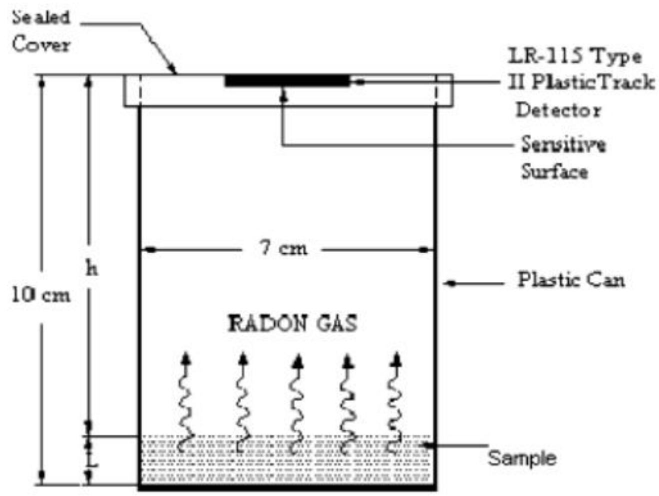

Figure 2: Experimental setup for the measurements of effective radium content and radon exhalation rates in soil samples

The sensitive part of the detector was facing the emanating radon from the soil samples so that it could record the tracks of alpha particles resulting from the decay of radon in the whole volume of the can. The cane was sealed to air tight with adhesive tape for 30 days. After fixed time, the detectors were retrieved, etched with 2.5 N NaOH at 60 ^{0}C for one and half hours. The etching was carried out to reduce the thickness of the LR-115 detectors to about 5 μm. Subsequently alpha tracks were counted using an optical microscope at magnification of 400×.

Theoretical Consideration

The track density ρ (in Track.cm^{-2}) is related to the radon activity concentration C_{Rn} (in Bq.m^{-3}) and the exposure time T by the formula [2, 6]:

$$\circ = KC_{Rn}T_e$$

Where

K (0.02tracks.m^{-2}.day^{-1}/Bq.m^{-3}) is the sensitivity factor of LR-115 detector with an uncertainty of about 15% for a can of height 10 cm and diameter 7 cm . The value of K depends on the height and radius of the measuring cylindrical can [2]. Once the radioactive equilibrium is established, one may use the radon alpha analysis for the determination of steady-state activity of radium. The activity of radon will increase with time T after closing of the cylindrical can, according to the relation [2, 6]: $C_{Rn} = C_{Ra}(1 - e^{-\lambda_{Rn} T})$

Where C_{Ra} is the effective radium content of the sample. Since a plastic track detector measures the time-integrated value of the above expression, i.e., the total number of alpha disintegrations in unit volume of the cylindrical can with a sensitivity K during the exposure time T, hence the track density observed is given by:

$$\rho = K C_{Ra} T_e$$

T_e is the effective exposure time which is related with the actual exposure time T and decay constant λ_{Rn} for ^{222}Rn with the relation [2, 6].

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

The effective radium content of the soil sample can be calculated by using the relation [6, 17, 18].

$$C_{Ra}(Bq.kg^{-1}) = \frac{\rho hA}{KT_e M}$$

Where M is the mass of the soil sample in kg, A is the area of the cross section of the cylindrical can in m^2 and h is the distance between the detector and top of the soil sample in meter.

The mass exhalation rate of the sample for release of radon can be calculated by using the expression [2,6].

$$E_x(M)(Bq.kg^{-1}d^{-1}) = C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\left(\frac{1}{T_e}\right)$$

The surface exhalation rate of the sample for release of radon can be calculated by using the expression [2, 6].

$$E_x(s)(Bq.m^{-2}d^{-1}) = [C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{T_e}]\frac{M}{A}$$

$$= E_x(M)\left(\frac{M}{A}\right)$$

Where λ_{Ra} is the decay constant for radium (^{226}Ra) and λ_{Rn} is the decay constant for radon (^{222}Rn).

Table 1 depicts the values of effective radium content, radon concentration, mass and surface exhalation rates of radon in for soil samples collected from different regions of Shire Indaslassie area Tigray region northern Ethiopia.

Table 1 *Effective radium content, radon concentration, and surface and mass exhalation rates of radon in different soil samples*

Sample No.	Corrected track density (Track.cm^{-2})	Radon concentration (Bq.m^{-3})	Effective radium content (Bq.kg^{-1})	Exhalation rates	
				Mass exhalation (Bq.kg^{-2} day^{-1}) E_x (M) × 10^{-6}	Surface exhalation (Bq.m^{-2}day^{-1}) E_x (s) × 10^{-5}
1	7571.2	47.4	47.4	12.57	32.65
2	17009.28	106.5	106.92	28.23	73.33
3	3500	21.9	22	5.8	15.07
4	1229.78	7.7	7.73	2.04	5.3
5	5382.72	33.7	33.84	8.93	23.2
6	9951.04	62.33	62.6	16.53	42.64
7	2518.4	15.76	15.83	4.18	10.86
8	13986	87.54	87.92	23.21	60.29
9	16571	103.72	104.17	27.5	71.43
10	14966.4	93.67	94.08	24.84	64.52
11	17588.8	110.08	110.56	29.19	75.83
12	19170.91	119.98	120.5	31.81	82.63
13	19949.23	124.86	125.4	33.1	85.97
	Mean	71.93	72.24	19.07	49.52
	Σ	42.26	42.44	11.2	29.1

From Table 1, we observe that the values of radium content and radon exhalation rates in soil samples are different at different places. That is due to the nature of the soil. Radon flux density

(i.e., 222Rn exhalation rate) depends upon a number of parameters that behave in a stochastic and independent fashion, such as the radioactive disintegration of ^{226}Ra to produce radon, the direction of recoil of radon in the grain, the interstitial soil moisture condition in the vicinity of the ejected radon atom and its diffusion in the pore space. It has been seen that the value of effective radium content in collected samples vary from 7.73 to 125.4 Bq.kg^{-1} with a mean value of 71.84 Bq.kg^{-1} and a standard deviation of 42.44 Bq.kg^{-1} . Among all values of effective radium content sample 12 and 13 have highest values. This value of radium content may be attributed to the coal mixed with the soil of samples. It has been seen from the Table 1 that effective radium content in soil of samples 2, 8, 9, 10 and 11 are little higher than that of the soil of samples 1, 3, 4, 5, 6 and 7. These higher values may be due to some red and white small stone pieces mixed with the soil which were grinded or there may be higher concentration of uranium.

It is also clear from the Table 1 that the mass exhalation of radon varies from 2.04 to 33.1×10^{-6} $Bq.kg^{-1}.day^{-1}$ with a mean value of 19.07×10^{-6} $Bq.kg^{-1}.day^{-1}$ and standard deviation 11.2×10^{-6} $Bq.m^{-2}.day^{-1}$. While the surface exhalation of radon varies from 5.3×10^{-5} to 85.97×10^{-5} $Bq.m-2.day^{-1}$ with a mean value of 49.52×10^{-5} $Bq.m^{-2}.day^{-1}$ and standard deviation 29.1×10^{-5} $Bq.m^{-2}.day^{-1}$.It is noteworthy from Table 1 and also Fig.1 that the effective radium content of soil samples is least in Indaslassie area (7.73 $Bq.kg^{-1}$) but highest in Tseadaemba village, part of Tahtay Koraro District (125.4 $Bq.kg^{-1}$). The values of radium content in soils are higher in the regions of Tseadaemba, which is a desert, mineral reach area, the soil types are monazite sands as well as literate the area is mountainous and rocky, especially granite in comparison with those from Indaslassie town. The majority of soil type is this region is literate that is a fine-grained soil created from weathering of rocks. Such soils contain high concentrations of iron oxides, iron hydroxides and high uranium content [8]. Its high uranium content is reflected by the high radium content, and the soil porosity plays an important role in radon exhalation. Thus, it is possible to analyze the present data to obtain a relation between radium content and radon exhalation rates. The mass and surface exhalation rates of soil samples are highest in samples collected from Tseadaemba village that is $33.1\times10^{-6}Bq.kg^{-1}.day^{-1}$ and $85.97\times10-5Bq.m^{-2}.day^{-1}$ respectively. A relative comparison of variation of effective radium content, mass and surface exhalation rates of radon with soil samples has been shown in Figs. 2, 3 and 4. It has been seen that there is a good correlation between them. It may be observed that the radon exhalation rates correspond to the estimated values of radium content.

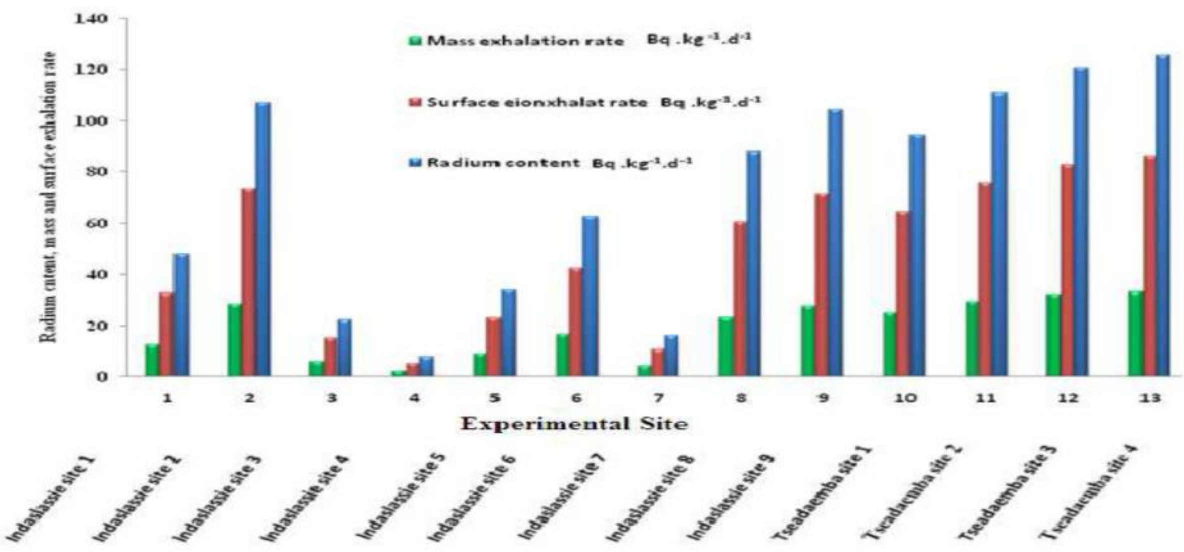

Figure 4: *The variation of effective radium content and radon exhalation rates with soil samples in different sites.*

The value of radium content and radon exhalation rates in soil samples reported in this thesis are corresponds with some researchers reported in different parts of the world [2, 4]. The values of effective radium contents and mass exhalation rate are lower than those reported for soil samples by Bhardwaj M.K et al, 2013 [18] of Mekelle, Ethiopia (i.e. the effective radium content varies from 11.56 to 312.83 $Bq.kg^{-1}$, mass exhalation rate varies from 3.55 to 96.49×10^{-6} $Bq.m^{-2}.day^{-1}$) while surface exhalation rate is greater (i.e. surface exhalation rate varies from 0.14 to $3.71\times10^{-5}Bq.m^{-2}.day^{-1}$). Some radium contents in these soil samples do correspond with the values for soils from Mekelle city, Tigray region, Northern Ethiopia. The maximum value of effective radium content in soil samples studied is also below the maximum permissible value of 370 $Bq.kg^{-1}$ as recommended by the Organization for Economic Corporation and Development (OECD).

CONCLUSION

Radium content, Radon concentration and radon exhalation rates (both the mass and surface exhalation rates) have been measured successfully using LR-115 plastic track detectors by the sealed can technique. The region under the study contains monazite sand, literate, loam, silt and clay in varying proportions. The radium distribution is found to be heterogeneous in the soil samples, varies from region to region in the same district. Its value is larger in samples from Tseadaemba village, than the samples from Indaslassie area. The values of radium content in soil samples of Tseadaemba site are higher value so this region is not safe as far as the health concern, because there is no lower safe limit of radon exhalation especially the people that live in this area are using ground water. So it may be contaminated with uranium, radium and radon and may cause different disease such as lung cancer, bone cancer, sores, lymphoma, kidney damage, born defects, cataracts teeth fracture and diseases that affect the formation of blood such as leukemia and anemia. After a long time earthquake may be expected. Because in this area there is certain amount of uranium this may cause tectonic force inside the earth crust.

The overall average value of radium content in the soil samples from these study area are found to be 72.24 $Bq.kg^{-1}$, while the global average value of radium content in the earth crust is known to be 40 $Bq.kg^{-1}$. The surface exhalation and mass exhalation rates of radon from these soil samples correspond to their radium contents. These exhalation rates are also higher for samples from Tseadaemba, than the samples from Indaslassie. The overall average of mass exhalation rate for the samples from the area under study is $19.07 \times 10-6$ $Bq.kg^{-1}.day^{-1}$ and the average value for surface exhalation rate of radon in the soil samples is 49.52×10^{-5} $Bq.m^{-2}.day^{-1}$. The radon concentrations of the soil samples are higher in Tseadaemba village than Indaslassie. The overall average of radon concentration is found to be 71.94$Bq.m^{-3}$, which is below the action level.

RECOMMENDATIONS

In the field of radiation detection and measurement negligible study has been done in Ethiopia. The present work suggests the following:

It needs due attention of the concerned body to find uranium, radium and radon concentration in various parts of the country. Measuring radium and radon so as to establish radium and radon "map of Ethiopia" for the future. Study of correlation between incidence of earthquake and radon level in earthquake prone areas of the country. Seasonal variation of radon and radon progenies should be study further.

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