INTERNATIONAL JOURNAL OF ENGINEERING AND MANAGEMENT SCIENCES
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ASSESSMENT OF HAZARDS DUE TO RADON'S MASS AND SURFACE EXHALATION RATES; AND RADIUM CONTENT IN SOIL SAMPLES OF LALIBELA, ETHIOPIA

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ABSTRACT
Radium is one of the natural radionuclide's found in soil and a decay product of uranium. Uranium is a radiotoxic element found in trace quantities in almost all natural occurring materials like soil, rock, etc. Radon an inert radioactive gas, whose predecessor is radium, is emitted from soil and from building materials. Everyone is exposed to radon because it is present everywhere with varying concentrations. Radon and its progeny are well established as cause of lung cancer. The effective radium content and radon exhalation rates in soil samples collected from Lalibela of Lasta district of Wollo province in Northern Ethiopia using LR- 115 Type-II plastic track detectors keeping in view the health hazard effects have been measured. Small pieces of LR- 115 Type-II film were fitted in bare mode in an emanation chamber for 30 days. The pieces of film were etched with 2.5N NaOH to reveal the alpha tracks recorded on it which were counted using polarized light optical microscope. The values of effective radium content are found to vary from 2.06 to 40.29 $Bq.kg^{-1}$ with a mean value of 15.05 $Bq.kg^{-1}$.The mass exhalation rates of radon vary from 0.062×10^{-5} $Bq.kg^{-1}$ $d^{-1}$to 1.21×10^{-5} $Bq.kg^{-1}.d^{-1}$ with a mean value of 0.47×10^{-5} $Bq.kg^{-1}.d^{-1}$. The surface exhalation rates of radon have been found to vary from 2.14×10^{-5} to 41.01×10^{-5} $Bq.m^{-2}.d^{-1}$ with a mean value of 15.6×10^{-5} $Bq.m^{-2}.d^{-1}$.The values of radium contents are found below the safe limit as recommended by Organization for Economic Co-operation and Development.

KEYWORDS: Effective radium content, Surface and mass radon exhalation rates, LR-115 type II plastic track detector, Plastic cylindrical cans, polarized light optical microscope

INTRODUCTION

Radium is a naturally occurring radioactive metal and presents in soil, sand, rock, water, plants and animals [1]. The naturally occurring radionuclides present in the soil are mainly ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. Radium is one of the radionuclides concern in soil [2]. It is a solid radioactive element under ordinary conditions of temperature and pressure. Radium gives off gamma radiation in soil grains, which can travel fairly long distances through air. Radium is chemically analogous to calcium, and is absorbed from soil by plants and passed up the food chain to humans. Microscopic quantities of radium in the environment can lead to some accumulation of radium in bone tissue whereby it degrades bone marrow and can mutate bone cells. Ingestion or body exposure to radium causes serious health effects which included sores, anemia, bone cancer and other disorders [1]. Due to its radioactivity property, there are several types of decay products that result from radium decay.^{222}Rn is one of the decay products of radium [3].

Radon (222Rn) is a naturally occurring alpha-emitting radioactive noble gas. It is produced during the natural decay chain of uranium. As radium decays, radon is formed and is released into small air or water containing pores between soil and rock particles. The exhalation of radon from soil involves two mechanisms, the emanation and transport. These mechanisms are affected by many factors including the properties of the soil [4].). When ^{222}Rn disintegrates it creates both short-lived and long-lived radon daughters. The long-lived radon daughters lead-210 (^{210}Pb) and polonium-210 (^{210}Po) has the ability to be stored in the human body. The elements above radon in the chain are relatively long-lived and of less concern for radiation exposure, but radon and the elements immediately following it in the chain are short-lived and therefore more hazardous[5].

When radium decays in soil grains, the resulting atoms of radon isotopes must first escape from the mineral grains to air filled pores. The rate at which radon escapes or emanates from soil to the surrounding air is known as radon emanation rate or radon exhalation rate of the soil. Radon exhalation describes the amount of radon passing through a surface, e.g., the ground surface or a wall per unit mass. Thus an important parameter is the radium content of the medium which is typically given as activity per unit mass or per unit surface area [6] . Radon exhalation is a complex phenomenon depending upon a number of parameters such as radium content in soil, soil morphology, and soil moisture content, soil grain size, temperature, atmospheric pressure, rainfall and vegetation [7-8]. So the measurement of radon exhalation rates of soil and rocks are helpful to study radon health hazard such as lung cancer due to alpha radiation internally and gamma radiation from soil externally [3-6] . In the present study, track etch technique has been used with LR-115 type II plastic track detector to measure the effective radium content of soil samples collected from the Lasta district district of Amhara state (Lalibela, Ethiopia).

Geological Detail of Study Area

Lalibela is a town in the Northern Amhara Region of Ethiopia. The town stands at an elevation of around 2,500 meters above sea level Lalibela (Figure 1) is located about 700 kms from north of Addis Abeba and its geographical coordinates is 12°02'N,39°02'E. It is highly dominated by uplands (mountains) which range from 1600 to 4200m.

Figure 1. Lalibela location map. Inlet (top right) shows the geographical distribution of the rock-hewn churches at the Lalibela monumental site (the study region)

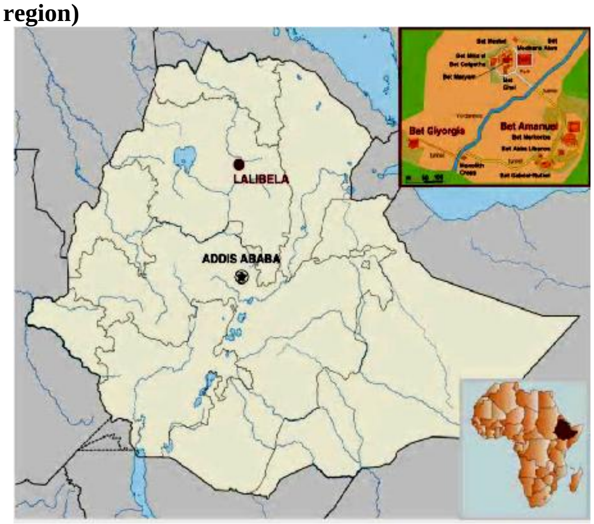

Fig. 1

Materials and Methods

Ten soil samples were collected from different places from study area with the gap of one to two km. then the samples were grinded and then dried in an oven to remove the moisture content completely. After drying, samples were sieved to obtain the fine quality of samples. About 175 gm of sample was enclosed in a plastic "cylindrical can" [13-15] and sealed for a period of three weeks in order to get secular equilibrium between radium and radon. After that, the mouth of the cylindrical can 10 cm height and d_1=6.5 cm and d_2=8.5 cm in diameter was sealed with a lid after fitting with LR-115 type-II plastic track detectors at the top inner surface of the can. The detector recorded the tracks of α- particles emitted by radon gas produced through the α-decay of radium.

The detectors were exposed for a period of one month. The detectors were retrieved and etched with 2.5N NaOH. The etching is carried out to reduce the thickness of the LR- 115 type – II detectors to about $5\mu m$ [16] subsequently, these α- particle tracks were counted using an optical polarized light microscope.

ANALYSIS

The effective radium content of soil samples was calculated using the formula [1, 17].

$$C_{Ra}(Bq.Kg^{-1}) = \left(\frac{\rho}{KT_e}\right)\left(\frac{hA}{M}\right) \qquad (1)$$

Where M is the mass of the soil in Kg, A is the cross sectional area of the cylindrical can in m^2, ρ is the track density in tracks cm^{-2}, h is the distance between the detector and the top of the soil in meters and k is (0.02 tracks.cm^{-2} d^{-1} per Bq.m^{-3}) [1] the sensitivity factor denotes the effective exposure time given by the expression;

$$T_e = \left[T - \frac{1}{\lambda_{Rn}}\left(1 - e^{-\lambda R_n T}\right)\right] \qquad (2)$$

The mass exhalation rate of the sample for the release of radon can be calculated by using the expression [18];

$$E_x(M) = C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{Te} \qquad (3)$$

Where λ_{Rn} and λ_{Ra} are decay constants of radon and radium respectively.

The surface exhalation rate of the sample for release of radon was calculated by using the relation [18]:

$$E_x(S)(Bq.m^{-2}.d^{-1}) = E_x(M)\left(\frac{M}{A}\right) \qquad (4)$$

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 [19]. The alpha indexes were determined using the following formula:

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

where C_{Ra} is the effective 226-Ra content ($Bqkg^{-1}$) in the building material. When its value exceeds 200 Bq kg^{-1}, it is possible that the radon exhalation from this material could cause indoor radon concentrations exceeding 200 Bq m^{-3}. On the contrary, when its value is below100 Bq kg^{-1}, it is unlikely that the radon exhalation from the building materials could cause indoor radon concentrations exceeding 200 Bq m^{-3}[20] .

RESULTS AND DISCUSSION

The result for radium concentration and radon exhalation rate in soil samples belonging to some area of Lasta district, Lalibela in Tables 1. The radium activity in soil sample of Lasta district varies from 2.06 to 40.29 Bq/kg. Radon exhalation rate in soil samples in terms of mass varies from $0.062x10^{-5}$ to $1.21x10^{-5}$ Bq kg^{-1} day^{-1}). The radon exhalation rate in terms of area varies from $2.14x10^{-5}$ Bq m^{-2} day^{-1} to $41.01x10^{-5}$ Bq m^{-2} day^{-1}.The value of radium content is found to be maximum in sample I-10 and minimum in sample E-1. In the sample I-10 the value of radium content is little higher than that of in other samples. This higher value may be due to the different geochemical distribution of this area. The values of radium activity determined in soil are less than the permissible value of 370 Bq/kg, which is acceptable for safe use OECD, 1979[21].Thus, results reveal that the area is safe as far the health hazard effects are concerned.

TABLE 1: Effective radium content, surface exhalation rates, mass exhalation rates and alpha index values in soil samples of Lalibela, Ethiopia

S.No	Detector code	Effective radium Content ($Bq.kg^{-1}$)	Mass exhalation rates ($Bq.kg^{-1}$ d^{-1}) E_x (M) $x10^{-5}$	Surface exhalation rates ($Bq.m^{-2}$ d^{-1}) E_x (S) $x10^{-5}$	Alpha Index value(I_α)
1	S-5	8.09	0.24	8.4	0.04
2	I-6	15.7	0.47	16.3	0.078
3	N-7	18.24	0.55	18.9	0.09
4	T-8	23.07	0.69	24.01	0.12
5	I-10	40.29	1.21	41.01	0.20
6	E-`1	2.06	0.062	2.14	0.01
7	WE-2	2.53	0.076	2.6	0.012
8	LE-4	4.08	0.12	4.2	0.02
9	LA-9	30.827	0.9	32.08	0.15
10	W-3	5.65	0.17	5.9	0.03
Mean		15.05	0.47	15.6	0.075
Standard deviation		12.42	0.39	12.92	0.057

CONCLUSION

The main target of this work was to assess the radium content and radon exhalation rates in the study area. The radium distribution is found to be heterogeneous as the radium content in the soil samples varies from place to place in the same district. The maximum values of effective radium content in the soil samples studied are also below the maximum permissible value of 370 Bq kg^{-1} recommended by the Organization for Economic Cooperation and Development, 1979. They will not produce dangerous radon levels in dwellings and this area itself may be used with the purpose of residence.

Radon exhalation study is important for understanding the relative contribution of the material to the total radon concentration found inside the dwellings. The calculated values of alpha indexes for these samples are much less than unity in each case. Therefore, it is concluded that the soil samples of this area are quite safe to be used as building materials.

ACKNOWLEDGMENTS

The authors are thankful to head of the department of physics (Yikdem Mengesha) & Ex-head Hagos Gebrehiwet Gebregergs , Dean and Ex-Dean of College of Natural and Computational Sciences, Mekelle University, Mekelle, Tigray Region, Ethiopia for providing the necessary facilities to carry out the experiment.

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