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Investigation of Radium Contents and Radon Exhalation Rates in Soil Samples in Menge District, Ethiopia

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Abstract: Radon has been recognized as one of the major contributor to the natural radiation and health hazards in the human dwellings, working places and mining areas. Even lung cancer is expected if it is present in enhanced levels beyond maximum permissible limit. We have studied radium contents and radon exhalation (both mass and surface) rates in Menge mining and non-mining areas of the Benishangul Gumuz region in Western Ethiopia using the sealed Can technique and LR-115 type II plastic nuclear track detectors. Fifteen soil samples were collected over the study area according to the fraction of the populations and mining and non-mining areas. It is found that the values of radium contents vary from 1.20 to 3.94 $Bq.kg^{-1}$ with an average value 2.44 $Bq.kg^{-1}$. It is also found that gold mining areas have had relatively higher radium contents as compared to the other samples which are collected from non-mining areas. And radon exhalation study is important for understanding the relative contribution of the material to the total radon concentration found inside the study area. The radon mass and surface exhalation rates for the studied samples had the mean values of 2.16×10^{-6} $Bq.kg^{-1}.d^{-1}$ and 1.14×10^{-4} $Bq.m^{-2}.d^{-1}$ respectively.

Keywords: Radium Contents, Radon Exhalation Rates, LR-115 Detector, Mining Areas, Menge District

1. 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 [1-5]. The natural radiation sources such as granite, soils sand water and food items contribute about 82% radiation dose received by human being. Soil is the main sources of continuous radiation exposure to humans [5]. 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 [6-7]. The naturally occurring radionuclides present in the soil are mainly Uranium (^{238}U), Radium (^{226}Ra), Thorium (^{232}Th) and Potassium (^{40}K). These radionuclides cause radiological hazard externally due to the gamma ray emission and internally due to inhalation of radon and its progeny [8]. When human exposure to natural radiation source is considered, radon and its short lived decay products in the environment are the most important contributors [9-13].

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). The global average of uranium content in the earth's crust is about three ppm [15]. 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 Radium, 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 [13-15]. 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 a-decay. 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]. If a uranium rich material lies close to the surface of the earth, there can be higher radon exposed hazards [8]. Thus, radon level in dwellings depends upon the radium content of the ground and building materials, also on how many radon atoms it contains. Texture and size of the grains, ambient temperature and pressure affects the indoor radon too [16-18].

Radium is one of the radionuclide of concern. This mainly enters the body in food and tends to follow calcium in metabolic processes to become concentrated in bones. The radiation given off by radium bombards the bone marrow and destroys tissue that produces red blood cells. It also can cause bone cancer. Radium is chemically similar to calcium and is absorbed from soil by plants and passed up the food chain to humans. The radium content of a sample also contributes to the level of environmental radon as radon is produced from ^{226}Ra through alpha decay. Higher values of ^{226}Ra in soil contribute significantly in the enhancement of environmental radon [7]. With this motivation, we address the radium contents and radon exhalation rates in soil samples collected from urban area of Menge district in the Western part of Benishangul Gumuz region which is located in Western Ethiopia. To realize the study, we have used LR-115 solid state nuclear track plastic detector (cellulose nitrate films) which is more sensitive to interact with alpha particles emitted from ^{222}Rn and recorded the information in the form of tracks or dots.

2. Research Methodology

2.1. Description of the Study Area

Figure 1. *Geographical location of the study area in Benishangul Gumuz region [26].*

Menge is one of the woreda in Benishangul Gumuz region of Ethiopia. It is bounded by Assosa in the South west, komesha in theWest, Sherkole in the north, kamashi zone in the northeast and the Dabus River on the east. This Woreda is 56 km from Assosa. It is small lowland Woreda with an area of just 1,500 km^2 consisting 22 administrative Kebeles and has around 44,000 population sizes. From these 96% of populations are depending on agriculture and traditional gold mining. We have selected Mengie because the miners may be affected by radiation exposures which are resulted from radon gas.

2.2. Materials and Technique

In order to carry out our experiment different instruments have been used. Such as oven used for drying samples to remove moisture content from soil samples, Mortar and Pestle for grinding soil samples, scientific sieve of 200 micron-mesh size used to separate wanted parts of the samples from the unwanted (to separate coarser from finer particles or for reducing soft solids to fine powder or just to filter fine powder of soil samples) one, plastic container of size 10 cm height and 7 cm width (diameter), 2.5 N NaOH at 60°C for chemical etching, polarized optical microscope at magnification of 400x for counting tracks caused by alpha particles that emitted from the samples and 3 cm X 3 cm fifteen (15) LR-115 plastic nuclear track detectors which are made up of cellulose nitrate having a formula $C_6H_8O_8N_2$ [15-16] for data recorded were used.

2.2.1. Experimental Design

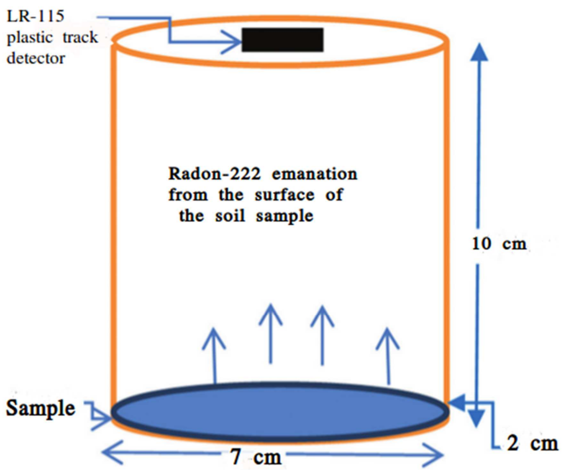

Figure 2. *Schematic diagram of sealed Can technique, LR-115 detector was suspended inside in the upper part of it.*

The sealed Can technique has been used for the measurement of radium contents and radon exhalation rates in soil samples. In our experiment fifteen soil samples were collected from different places of the study area of Menge District 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 mineral rich soil. The soil samples were dried in an oven at about 110°C for 3 hours in order to remove the moisture content completely and each soil samples 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 g of each sample was packed and sealed in an air tight leak proof plastic Can of size 10 cm in height and 7 cm in diameter, which was closed for a period of about one month in order to get equilibrium between radium and radon progenies. After that, LR-115 type II plastic nuclear track detector fitted on the top inner side of the Can for three Moths exposure time from December 1, 2017 to February 30, 2018.

After three months exposure period, we have removed the detectors and have taken chemical etching. At normal condition the alpha tracks are not visible. Therefore, chemical etching is the best way to enlarge the tracks size to be observed under polarized optical microscope. In this study, 2.5 N NaOH solutions was poured into each beaker and were used for 80 minutes at 60°C temperature oven and the beakers have removed from oven and the films have been washed by distilled water to remove the dust particles from etched films and made the tracks countable under polarized optical microscope.

2.2.2. Data Analysis

The research data would have been analyzed by well-established mathematical expressions. The radon concentrations and radium contents of the soil samples have calculated by using the relations [18-24]:

$$C_{R_n} = C_{R_a}\left(1 - e^{-\lambda_{R_n}T}\right) \quad (1)$$

$$C_{R_a} = \frac{\rho h A}{K T_e M} = C_{R_n}\frac{V}{M} \quad (2)$$

Where K (=1.075 tracks $cm^{-2}day^{-1}$ $(Bqm^{-3})^{-1}$) is the correction or calibration factor of the detector [2, 15], ρ is the surface density (tracks cm^{-2}), h is the distance between the top of the container and the top of soil samples (m), A is the area of the can (m^2), M is the mass of the soil sample (kg), T_e is the effective equilibrium time which is related with the actual equilibrium time (exposure time) T, V is the volume of the Can, C_{Rn} is the radon concentration (Bqm^{-3}) and decay constant λ_{R_n} for ^{222}Rn with the relation. The general formula to calculate the effective equilibrium time is [18-24]:

$$T_e = T - \lambda_{R_n}^{-1}\left(1 - e^{-\lambda_{R_n}T}\right) \quad (3)$$

The mass and surface exhalation rate of the sample for release of radon can be calculated by using the expressions [18-24]:

$$E_x(M) = C_{R_a}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{T_e} \quad (4)$$

$$E_x(S) = E_x(M)\frac{M}{A} \quad (5)$$

Where λ_{R_a} is the decay constant of ^{226}Ra, M mass of sample in kg and A is the base area of sample container in m^2.

3. Results and Discussion

The values of radium content, mass exhalation rates and surface exhalation rates in the soil samples collected from area within two kilo-meters around Down Kebeles', Menge district, Benishangul Gumuz Region, Ethiopia, are depicted in table 1, figure 3, figure 4 and figure 5 respectively.

Table 1. *Radium contents, radon mass exhalation rates and radon surface exhalation rates for the studied soil samples.*

Sample codes	C_{Ra} in Bq/kg	E_X (M)*10^{-6} in Bq/kg.d	E_X (S)*10^{-4} in Bq/d.m^2
S-1	3.00	5.35	1.39
S-2	3.01	5.57	1.45
S-3	3.10	5.53	1.44
S-4	2.00	3.61	0.94
S-5	2.20	3.92	1.02
S-6	3.20	5.71	1.49
S-7	2.70	4.82	1.25
S-8	2.82	5.03	1.31
S-9	2.07	3.69	0.96
S-10	1.20	2.14	0.56
S-11	1.86	3.32	0.86
S-12	3.94	7.03	1.83
S-13	1.24	2.21	0.58
S-14	3.04	5.42	1.41
S-15	1.21	2.16	0.56
Mean	2.44	4.37	1.14

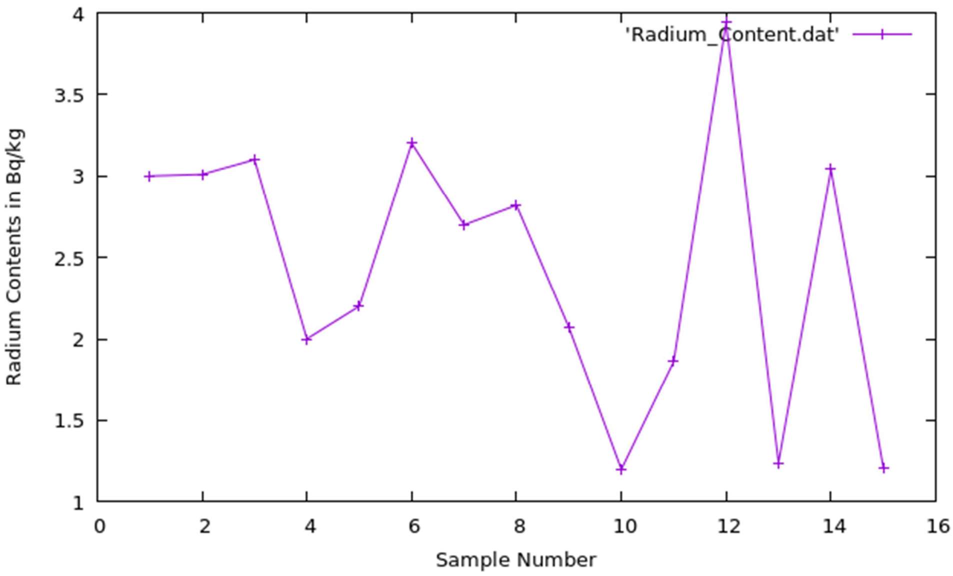

Figure 3. *The radium content at different weights of soil sample on the used LR-115 type II plastic nuclear track detectors.*

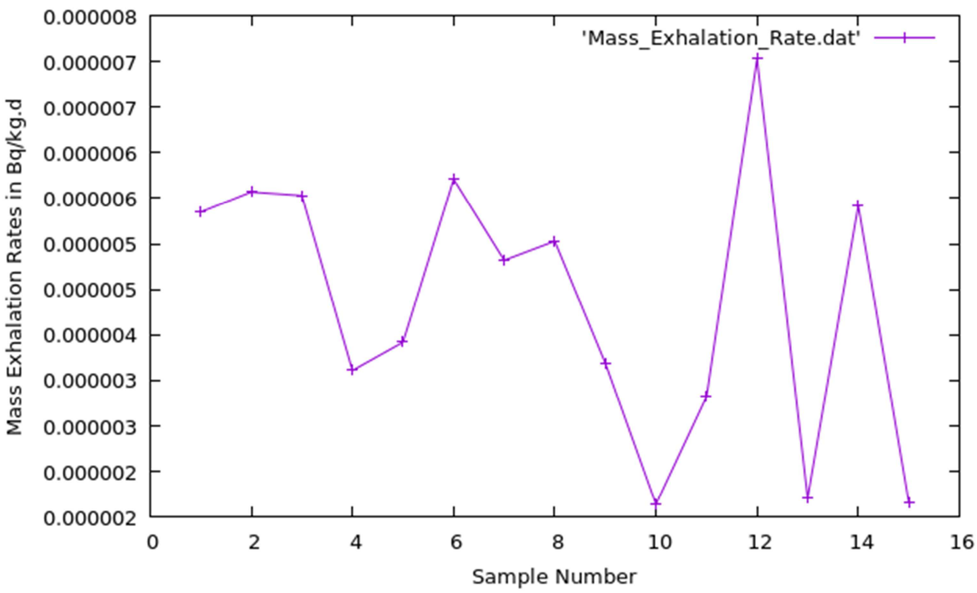

Figure 4. *The mass exhalation rate at different weights of radon source on the used LR-115 type II plastic nuclear track detectors.*

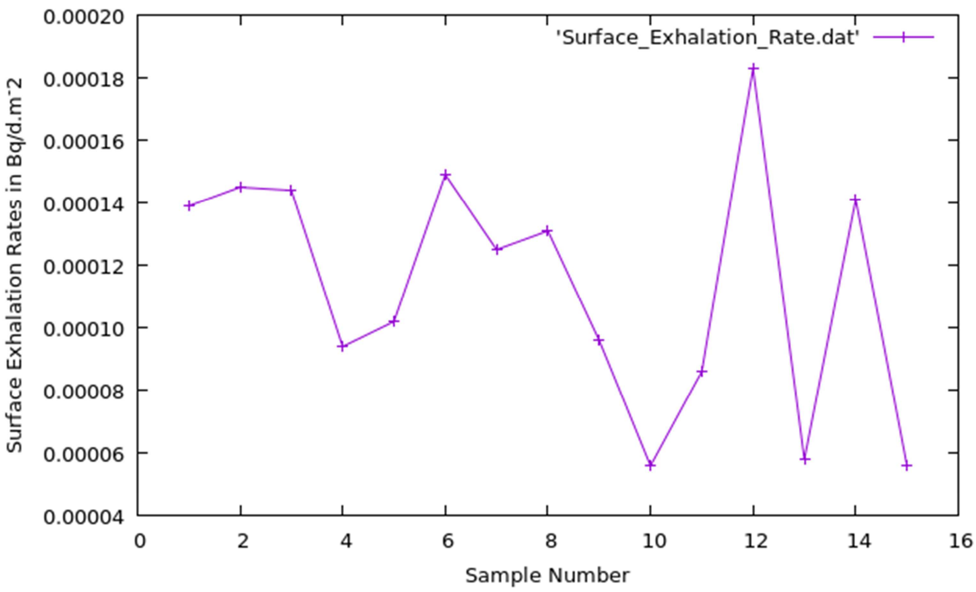

Figure 5. *The surface exhalation rate at different weights of radon source on the used LR-115 type II plastic nuclear track detectors.*

The values of effective radium content, radon mass exhalation rates and surface exhalation rates in the soil samples collected from area within two kilometers around, Menge district, Benishagul Gumuz Region, Ethiopia are depicted in table 1. We have observed that the values of radium contents and radon exhalation rates in soil samples are different at different places. That is due to the nature of the soil.

The radium content was found to be varied values which indicates that the mining areas have presented with higher values than the non-mining areas. In this context, the mineral miners must have safety materials. But due to lack of knowledge about radiations, they have no any safety materials since the miners are mining the minerals (specially gold) using traditional mining system, because, 100% of the miners are farmers (not educated). That were what we have observed during sample collection.

For comparison, the average radon concentrations have been found to be in the range of the IARC action level of 200 to 600 Bq.kg^{-1} [25], while around 20% of the studied samples have the values below this action level. As evident from the data of this study that already have mentioned, among all the selected places, the maximum radium contents and radon exhalation rates were recorded around the mining areas.

Based on this observation, whether the radium contents and radon concentrations are below the world's action levels or above, their health could be affected in the holes during mining time since these holes are their work places for them. So that comparing the results of this study with the overall action levels in the world never has credited, because of their traditional life style.

Different ventilations systems are very interested and advised for our populations settled into not only the study area but also the general population. But the other methods are used for modernized life styles. Even implementing depressurizations in the foundations is not cultured in modernized citizens of Ethiopia.

4. Conclusion

Radium content and radon exhalation rates (both the mass and surface exhalation) have been measured and analyzed using LR-115 type II plastic nuclear track detectors successfully by the sealed Can technique and have plotted by gnuplot respectively. The radium distribution was found to be heterogeneous as the radium content in the soil samples varies from place to place in the same district. Its value is larger in samples which were taken around mining areas, than other samples. The values of radium content in soil samples with higher value so in this district is not safe as far as the health concern, because there is no lower safe limit of radiation concentration. Radium contents value were varied based on several factors including geographical location and mining and non-mining areas in the study area nature.

The values of radium contents (radon's parent) was varied from 1.20 $Bq.kg^{-1}$ to 3.94 $Bq.kg^{-1}$ with the average value of 2.44 $Bq.kg^{-1}$. The radon mass and surface exhalation rates were also studied for those soil samples and have found the values varied from 2.14×10^{-6} $Bk.d^{-1}.kg^{-1}$ to 7.03×10^{-6} $Bk.d^{-1}.kg^{-1}$ with average value of 2.16×10^{-6} $Bk.d^{-1}.kg^{-1}$ for mass exhalation rates and 0.56×10^{-4} $Bq.d^{-1}.m^{-2}$ to 1.83×10^{-4} $Bq.d^{-1}.m^{-2}$ with average value of 1.14×10^{-4} $Bq.d^{-1}.m^{-2}$ for surface exhalation rates respectively. Which have indicated that the gold miners are under the risk of radiations health hazards.

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