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RESEARCH ARTICLE

MEASUREMENTS OF ACTIVITY CONCENTRATION OF NATURAL RADIONUCLIDES IN THE DIFFERENT COFFEE SAMPLES COLLECTED FROM SHASHAMENE MARKET, ETHIOPIA

***Rukiya Aliyi and Chaube, A.K**

Physics Department, Addis Ababa University, Addis Ababa, Arat Kilo, Ethiopia

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ABSTRACT

Four raw coffee samples purchased from Shashamene markets in Ethiopia were analyzed by High Pure Germanium (HPGe) gamma spectrometry to determine the activity concentrations of the natural radionuclides ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. All samples were found to contain a high mean content of ^{40}K. They had 591.185 Bq/Kg average values of ^{40}K concentrations that were higher than the acceptable value 412 Bq/kg. The average values of radium equivalent for different coffee samples in area under investigated was 47.44Bq/kg which is lower than the recommended maximum value 370 Bq/kg. The average values of absorbed dose rate (Dr), Dout, Din, and Dtot , external (Hex) and internal (Hin) hazard index due to the emitted ¥ -rays of the coffee respectively was of 26.49nGy h^{-1}, 0.0325, 0.181, 0.107 mSv /year , 0.128 and 0.128 these values were all lower than the assigned worldwide values of 0.08, 0.42, and 0.50 mSvyear-1, respectively. Radioactivity level index ranged from 0.36 to 0.475 Bq.kg-1with average value is 0.4 Bq. kg^{-1}. The average value of Radioactivity level index is lower than one the recommended safe limit ≤1. Therefore, the coffee had no radiation hazard. Hence it can be concluded that the radionuclide concentration of measured coffee samples were poses no radiological hazard to the public.

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INTRODUCTION

Coffee is one of the most popular and widely consumed beverages in the world, and its consumption is increasing (Roselli C, 2013). However, variation exists in the annual consumption between countries. In addition, coffee is grown in many countries, where the coffee trade has played a crucial role in their economic development (Roselli C *et al.* 2013). Coffee comes from the plant genus Coffea, which has two primary species, C. Arabica (Arabica) and C. canephora (known as C. obusta). Ethiopia is the world's seventh largest producer of coffee, and Africa's top producer, with 260,000 metric tonnes in 2006 (Food and Agricultural commodities production, 2010). Half of the coffee is consumed by Ethiopians (*Cousin, Tracey L, 1997*) and the country leads the continent in domestic consumption (Major coffee producers, 2010). The major markets for Ethiopian coffee are the EU (about half of exports), East Asia (about a quarter) and North America (Keyzer, Merbis &Overbosch 2000). The total area used for coffee cultivation is estimated to be about 4,000 km^2 (1,500 sq mi), the size is unknown due to the fragmented nature of the coffee farms (Belda, 2006).

****Corresponding author:*** **Rukiya Aliyi,**
Physics Department, Addis Ababa University, Addis Ababa, Arat Kilo, Ethiopia

The way of production has not changed much, with nearly all work, cultivating and drying, still done by hand (*Cousin, Tracey L. June 1997).* The revenues from coffee exports account for 10% of the annual government revenue, because of the large share the industry is given very high priority, but there are conscious efforts by the government to reduce the coffee industry's share of the GDP by increasing the manufacturing sector (Belda, 2006). Some naturally occurring radioisotopes and other elements present in soil are drawn into the roots of plants via ion channels or specific transporters (Sugiyama H *et al.* 2009). Their distribution throughout the plant tissues depends on their chemical characteristics and several parameters of soil and the plants themselves (Awudu AR *et al.* 2012). Primarily the physical-chemical characteristics of the soil are the main parameters which determine the quantity of accumulated radioactive substances in the plant organs. Some plants are capable to incorporate large amounts of radioactive substances in their tissues without visible and provable changes; however their consumption can cause serious impairments and diseases in the human organisms and the human. Of course, it may have a negative impact on the growth and development of plants if it is a matter of a stronger intensity of radioactive radiation. The radioactive contamination of the organs and the body tissues of animal organisms basically depend on the level of contamination of the food they consume, and to a less extent it depends on drinking water and inhalation (A.G. Kudryasheva *et al*. 1997). The natural radionuclides by means of migration come from the soil to the crops and contribute for total radiation burden in the population. Considering the fact that they can cause undesired effects on the human organism, it is necessary to determine the content of radionuclides in the surrounding, and on the basis of the obtained results the dose which the human receives should be calculated. However, it turned out that the understanding of the behavior of the natural radionuclides in the environment is very important, because such information can be used as the related parameter values for radiological assessments (Vera Tome, 2003).

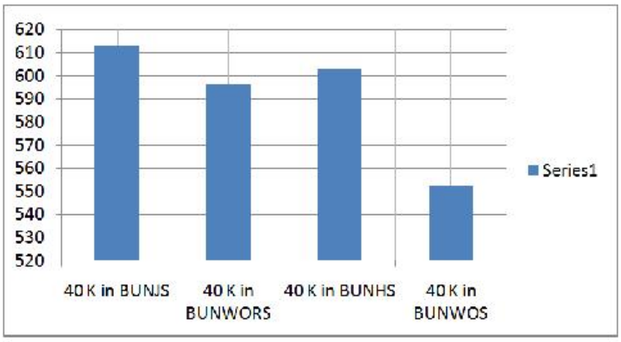
MATERIALS AND METHODS

Sample Collection and Preparation: Four raw coffee samples were purchased at markets in Shashamene, Ethiopia. Each was roasted and grinded and weighing. The samples were then transferred to polyethylene Marinelli type beakers of known weight were hermetically sealed with an insulating tape to impede contact with air moisture say labeled, and packed into radon-impermeable plastic containers to prevent radon gas escape as much as possible. The samples were stored and kept for a period of 1 month to attain secular radioactive equilibrium among ^{226}Ra, ^{232}Th, and their respective short-lived decay products ^{226}Ra and its decay products in the uranium series and ^{228}Ra and its decay products in the thorium series (Kurnaz A,2007, Samad MA,2012). Finally, each Marinelli container was analyzed using aHPGe detector.

RESULT AND DISCUSSIONS

The results of the present study on the coffee samples are summarized one by one as follow. Detection of the amount of natural radioactivity for ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K in coffee powder samples was carried out with gamma spectrometry using a high-purity germanium (HPGe) detector with a 70% relative efficiency and a resolution 1.9 keV for the 1332.5 keV^{60}Co gamma line and MCA with 2000 channel. The background radiation and the samples were counted 36,000s.

prominent photo peaks of all radio- nuclides daughter peaks were calculated by subtracting the respective count rate from the background spectrum obtained for the same counting time. Then the activity of the radionuclide is calculated from the background subtracted area prominent gamma ray energies (El-Shershaby A, 2006).



Bar graph 1. Activity of 40 K Radionuclides in the sample BUWOS

During our experimental activities our detector could identified only potassium-40 in the coffee samples. All coffee samples had 591.185 Bq/Kg average values of ^{40}K concentrations that were higher than the acceptable value (412 Bq/kg) (UNSCEAR, 2010). The values of radium equivalent for different coffee samples in area under investigated were calculated by using equation below these values presented in table4 and values ranged from 42.5 to 54.92 Bq/kg with average value 47.44Bq/kg which is lower than the recommended maximum value 370 Bq/kg (Gilmore, 2008).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K$$

WhereC_{Ra}, C_{Th} and C_K are the average activity concentration in the sample in Bq/kg of^{226}Ra, ^{232}Th, and ^{40}K respectively (K. M. Dabayneh, 2008)

The calculated values of absorbed dose rate (Dr) were found to vary from 23.73 to 30.67nGy h^{-1}, with an average value of 26.49nGy h^{-1}.

Table 1. The measured Activity concentration level of natural radionuclides in the Coffee samples collected

Sample ID	Activity concentration Bq/kg
	^{40}K
BUNJS	613.28 ± 45.995
BUNWORS	596.35 ± 33.878
BUNHS	603.12 ± 38.165
BUWONS	551.99 ± 31.0000

Table 2. Radium equivalent, absorbed dose rate, annual effective dose rate, external hazard index, and internal hazard index in different coffee samples

Sample ID	RaeqBq/Kg	Dr(nGy/h)	Dout(mSv/y)	Din(mSv/y)	AEDE	Hex	Hin	I_γ
BUNJS	54.92	30.67	0.0376	0.210	0.2476	0.148	0.148	0.475
BUNWORS	45.91	25.64	0.0315	0.176	0.215	0.124	0.124	0.397
BUNHS	46.44	25.93	0.0318	0.178	0.2098	0.125	0.125	0.4
BUNWONS	42.50	23.735	0.0291	0.163	0.1921	0.115	0.115	0.36

The 295.21 and 351.92 keV of ^{214}Pb and 609.31, 1120.29 and 1764.49 keV of ^{214}Bi gamma ray lines were used to determine the ^{238}U activity concentration. The ^{232}Th activity concentration was determined using 238.63 keV of ^{212}Pb, 911.21 and 968.97 keV of ^{228}Ac gamma lines. The activities of ^{40}K and ^{137}Cs were determined directly from the 1460.8 and 661.6 keV gamma lines, respectively. The net count rate under the most

The measured average absorbed dose rate in the air was lower than the recommended international levels of 55 nGy h^{-1}(Turner J *et al*., 2007) and the coffee was safe for use. The calculated indoor, outdoor, and total AEDE values are presented in Table 4. Calculated average values for Dout, Din, and Dtot respectively

0.0325, 0.181, and 0.107 mSv /year to global measured values, these values were all lower than the assigned worldwide values of 0.08, 0.42, and 0.50 mSvyear-1, respectively (UNSCEAR, 2000).The external (Hex) and internal (Hin) hazard index due to the emitted ¥ -rays of the coffee samples were calculated and examined according to the following criterion:

The value of Hex must be lower than unity in order to keep the radiation hazard insignificant. This is the radiation exposure due to the radioactivity from a construction material, limited to 1.5 $mGy\cdot y^{-1}$. The maximum values of Hex equal to unity correspond to the upper limit of Raeq (370 $Bq\cdot kg^{-1}$) (48). The calculated external hazard index values were found to vary between 0.115 and 0.148 with average value of 0.128 these values are less than unity, which is 87.2 % less than recommended value.

The calculated internal hazard index values were found to vary between 0.115 and 0.148 with average value of 0.128, which is 87.2% less than recommended value (Knoll G.F, 2000). Radioactivity level index ranged from 0.36 to 0.475 Bq.kg-1with average value is 0.4 Bq. kg^{-1} (Table 4).

The average value of Radioactivity level index is lower than one the recommended safe limit ≤ 1 (Van Rooyen T.J., 2002). Therefore, the coffee had no radiation hazard. Hence it can be concluded that the radionuclide concentration of measured coffee samples were poses no radiological hazard to the public.

Conclusion

During our experimental activities our detector could identified only potassium-40 in the coffee samples. All coffee samples had 591.185 Bq/Kg average values of ^{40}K concentrations that were higher than the acceptable value (412 Bq/kg) (UNSCEAR, 2010). To assess the radiological risk, the mean values of the radium equivalent, absorbed dose rate, annual effective dose rate, Hex, Hin and were estimated, and all values were less than the allowable limits reported by UNSCEAR, 2010.Hence it can be concluded that the radionuclide concentration of measured coffee samples were poses no radiological hazard to the public.

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