Research Article

Study of Natural Radionuclide in Some Plants Food from Karo District Post Eruption of Mount Sinabung North Sumatera

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Abstract

Natural radionuclides of plants food are the main sources of internal radiation exposure in human. Mount Sinabung is one of the active volcanoes which in the past 10 years it has been always shown a continuous activity until to date. The study was carried out to evaluate the natural radionuclides concentration in soil and some food grown in Karo District. The soil and food crops sample collected from Karo District were analysed by means of Gamma Spectroscopy for radionuclides ^{226}Ra, ^{232}Th and ^{40}K. The concentration radioactivities in food crops were follows ^{226}Ra and ^{232}Th could not detected, ^{40}K = 124,81 ± 3,59 Bq/Kg. Transfer factors are the most important parameters required for mathematical modeling used for environmental impact assessment of radioactive contamination in the environment. The result showed that the transfer factor for ^{226}Ra and ^{232}Th were not found because very low concentration and ^{40}K was 0,27. The annual internal dose received by domestic population living in District Karo due to the consumption of the foodstuff was 0,0103 mSv/year which is very much lower than annual dose limit of 1 mSv for general public.

Keywords: natural radionuclides, plant crops, mount Sinabung, transfer factor, annual dose

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Introduction

Mount Sinabung is one of the active volcanoes located in Distric Karo, North Sumatera and it is site at 03^{0}10' N and 98^{0}23' E with an altitude of 2460 m above sea level. Mount Sinabung has erupted many times. Within the last 10 years Mount Sinabung has shown some activities, on August 27, 2010 and then in 2013 again a prolonged eruption to the present. The activity of volcanos can cause potentially life-threatening hazard that is in the form of primary hazard such as lava flows, hot cloud, poisonous gas, incandescent stone and ash rain, while the secondary danger is cold lava.

The eruption of the volcano brought out a thick cloud of black smoke with sand and volcanic ash. Volcanic ash or volcanic sands are volcanic mineral drops that are ejected into the air during an eruption. Volcanic ash and sands are made up of fine to large-sized rocks, of which the fine size can fall at distances of hundreds to thousands of kilometers, while large ones usually fall around the radius of 5-7 km from the crater [1]. The eruption of lava flows, volcanic ash, cold lava floods are rocks and minerals derived from volcanoes containing mineral metals, heavy metals and natural radionuclide elements with K, U, and Th isotopes commonly present in magma or Material released by volcano [2].

Many researchers have shown that volcanic debris contains natural radioactive elements, such as Marpaung et al [3] has conducted a Natural Radionuclide Analysis on volcanic dust and cold Lava of Sinabung Mountain of Karo Regency by Using Neutron Activation Analysis Method (NAA) and the result of qualitative analysis shows that natural radionuclide contained in volcanic ash and cold lava is Uranium (U) and Thorium (Th). Various amount of natural radionuclide present in soil can eventually be found in foods consumed by humans through plants that absorb radioactive elements via their uptake by plants rooting system. The uptake of radionuclides from soil to plants is widely measured by the transfer factor (TF), which serves as a prediction for the amount of radionuclide accumulates in the plant. The migration and accumulation of contaminants in cultivated soils is complex, such as leaching, capillary rise, runoff, sorption, root uptake and re-suspension into atmospher [4]. With the accumulation of radionuclides in food obtained from plants will result in total internal dose of radiation received by the human body [1, 5, 6].

This paper present the results of the radiologic survey carried out in village close to Mount Sinabung during the recent eruption. We focus on the abundance of the natural elements K, Ra and Th.

Materials and Methods

Study area

The study area is located at the vicinity of Mount Sinabung in the Guru Kinayan village and Juma Kuta Mbaru. The Guru Kinayan site $3^0$143'279" N – $98^0$401'815" E is located about 3 Km of the Mount Sinabung and Juna Kuta Mbaru site $3^0$114'667" N – $98^0$394'467" E is located about 7 Km of the Mount Sinabung.

Sample collection

The coordinate data of all sampling sites is determined using a personal GPS navigator. 2 kg of soil samples were taken with a depth of 5-20 cm from the surface of the soil where gravel, stone, roots and dust were removed from the sample, then inserted into a plastic container, firmly stamped and labeled sample information. At the same site the plant samples were collected in the form of maize, chilli, cabbage and green leaf, which were taken in fresh condition. Each sample of the plant is collected each of 7 kg then washed, cleaned of the ground particles attached, if needed peel skin sample then dried, then inserted into plastic containers to reduce decay organically.

Sample preparation

Wet soil and plant samples are allowed to dry until they reach a constant weight at room temperature. Samples that have been dried at oven at 105 ^{0}C temperature for 5 hours, refrigerate then mashed with pestle and mortar. The sample was reduced in size by means of filtered using a mesh size of 200 mesh for the soil and a size of 100 mesh for the plant. Samples obtained in powder form and insert into Marinelli baeker up to 1 L volume. Cover tightly with glue araldite and label the caption. Samples were allowed to stand for one month to reach the secular equilibrium and the daughters radionuclides in the environment sample.

Radioactivity measurements

The measurements of the radionuclides in the prepared samples were carried out by using GEM F5930 ORTEC type coaxial high purity Germanium (HPGe) detector. The detector was coupled to a multi channel computer based analyzer. The gamma ray spectrum is recorded using a Personal Computer based 4096 channel analyzer and processed using ORTEC Vission-32 Gamma spectrum analysis computer software.

The detection efficiency calibration and energy of the system for the determination of radionuclides in the prepared samples was carried out using sources of standard radioactive solids known to be incorporated into GEM F5930 ORTEC model HPGe detectors. Standard sources are enumerated for 3 hours. The results obtained in the form of peak energy snippet and channel number. The relationship between the channel number and energy produces energy calibration for qualitative analysis while calibration efficiency for quantitative analysis is the relationship between energy with enumeration efficiency.

The measurement for prepared sample was carried out in the counting room located in the basement of laboratory building. The measurement time for the samples and background was 17 hours. The background counts were used to coreect the net peak area of gamma rays af measured isotopes. Quality assurance was addtionally guarented by regular participations in national and international intercomparation exercise.

The gamma energy peaks 351,92 keV of ^{212}Pb and 609,31 keV of ^{214}Bi were used to determine ^{226}Ra. The gamma energy peaks 911,07 keV of ^{232}Th and that of ^{40}K was determined from the gamma energy peak of 1460,83 keV.

The activity concentrations (C_{avg}) of ^{226}Ra, ^{232}Th and ^{40}K in Bq Kg^{-1} for the samples were determined using the following expression:

$$C_{avg} = \frac{N_{SP} - N_{BG}}{\varepsilon_{\gamma} \cdot p_{\gamma} \cdot W_{SP}} \qquad (1)$$

where; N_{sp} = net counts of a sample peak at energy E, N_{Bg} = net counts of a background peak at energy E, $Є_{\gamma}$ = the counting efficiency of the detector system at energiy E, P_{γ} = the gamma ray emission probability (gamma yield) at energy E, W_{sp} = mass of sample (Kg). If there is more than one peak in the energy analysis range for a radionuclide, then an attempt to average the peak activities is ade. The results are then the weighted average radionuclide activity.

Calculation of effective dose

In order to assess the ingestion dose of radionuclides, it necessary to determine the annual activity intake per inhabitant for each ingested radionuclide. The intake of radionuclides by the ICRP (International Commission on Radiological Protection) Human Alimentary Tract Model [7]. To derive ingested dose, the ingested annual activity of each radionuclide is multipled by its dose convrsion coefficient. Finally, the total ingestion dose is obtained by summing the contribution of all radionuclides.

The annual intake (D) for ^{226}Ra, ^{232}Th and ^{40}K from plants food in the present work were determed by using the activity concentration (C_{sp}) in foodstuff and the annual food consumption rates (I) by the Karo Region population based on the Food Security Agency Karo Region, 2016 Estimation of the annual internal effective dose (D) was calculated by using the following equations [8]:

$$D = C_{sp}\ x\ I\ x\ IDCF \qquad (2)$$

where D is the annual effective dose (Sv y^{-1}) due to ingestion of radionuclides from the consumption of foodstuffs (Bq Kg^{-1}), I is the annual intake of foodstuff (Kg y^{-1}) and IDCF is the ingested dose conversation factor for radionuclides (Sv Bq^{-1}). IDCF values used for ^{226}Ra, ^{232}Th and ^{40}K are 0,28.10^{-3}, 0,22 10^{-3} and 6,2. 10^{-6} Sv Bq^{-1} respectively.

Result and Discussion

Radionuclides concentrations in soil and plants food

Calibration energy and efficiency curves show in **Figures 1** and **2**. The results obtained in the form of peak energy snippet and channel. The relationship between the number of channel and energy produces energy calibration for qualitative analysis while calibration efficiency for quantitative analysis is the relationship between energy with enumeration efficiency.

The result of the activity concentration measurements in soil and plants food are presented in **Tables 1** and **2**.

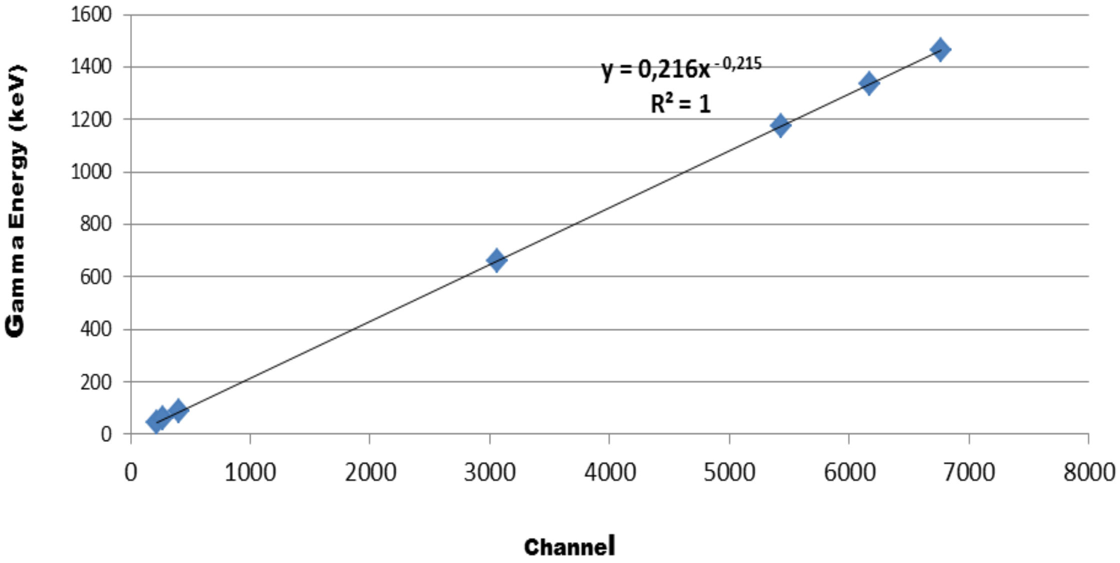

Figure 1 Calibration energy curve

Table 1 shows that, the concentration of natural radionuclides obtained by value varies depending on their geological structure. The highest value of the highest concentration of natural radionuclides was found in the ^{40}K at Guru Kinayan soil sample of 570.06 ± 15.48 Bg/Kg, while for the ^{226}Ra and ^{232}Th the highest radionuclide concentrations were found in the Juma Kuta Mbaru soil sample of 25.01 ± 1.12 Bq/Kg and 67.81 ± 2.67 Bq/Kg. The lowest concentration of natural radionuclides was found in the ^{226}Ra and ^{232}Th in Guru Kinayan's soil sample were 19.53 ± 0.83 Bq/Kg and 45.43 ± 2.00 Bq/Kg respectively, whereas the lowest concentration of radionuclide for the ^{40}K was found in Juma Kuta Mbaru's soil sample of 398.21 ± 12.40 Bq/Kg. The concentration of Potassium-40 is higher than that of other radionuclide concentrations. Potassium-40 is known as the most natural radionuclides in food and the human body. Potassium-40 in soil is an important element that affects the growth and fertility of plants [7]. **Figure 3** shows the compare activity radionuclides in soil between Guru Kinayan and Juma Kuta Mbaru.

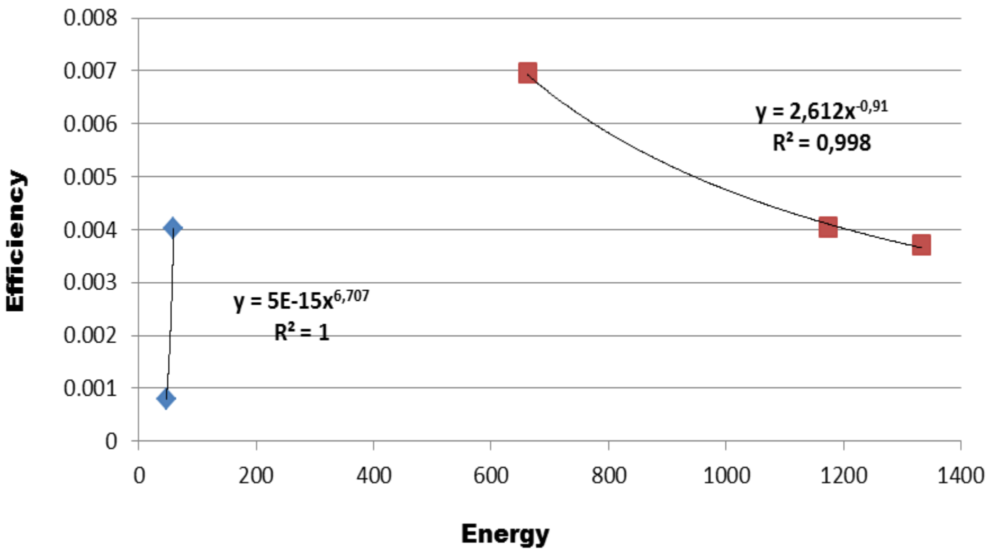

Figure 2 Calibration efficiency curve

Table 1 Activity concentration of natural radionuclides in soil

Type of sample	**Activity concentration (Bq/Kg fresh weight)**		
	^{226}Ra	**^{232}Th**	**^{40}K**
Soil in Guru Kinayan	19,53 ± 0,83	45,43 ± 2,00	570,06 ± 15,48
Soil in Juma Kuta Mbaru	25,01 ± 1,12	67,81 ± 2,67	398,21 ± 12,40

Table 2 Activity concentration of natural radionuclides in plants food

Type of sample	**Activity concentration (Bq/Kg fresh weight)**		
	^{226}Ra	**^{232}Th**	**^{40}K**
Corn in Guru Kinayan	Undetectable	Undetectable	32,35 ± 1,47
Chili in Guru Kinayan	Undetectable	Undetectable	137,92 ± 3,92
Cabbage in Guru Kinayan	Undetectable	Undetectable	180,41 ± 4,84
Leek in Guru Kinayan	Undetectable	Undetectable	113,29 ± 3,41
Corn in Juma Kuta Mbaru	Undetectable	Undetectable	26,29 ± 1,28
Chili in Juma Kuta Mbaru	Undetectable	Undetectable	135,57 ± 3,85
Cabbage in Juma Kuta Mbaru	Undetectable	Undetectable	190,19 ± 5,08
Leek in Juma Kuta Mbaru	Undetectable	Undetectable	182,44 ± 4,88

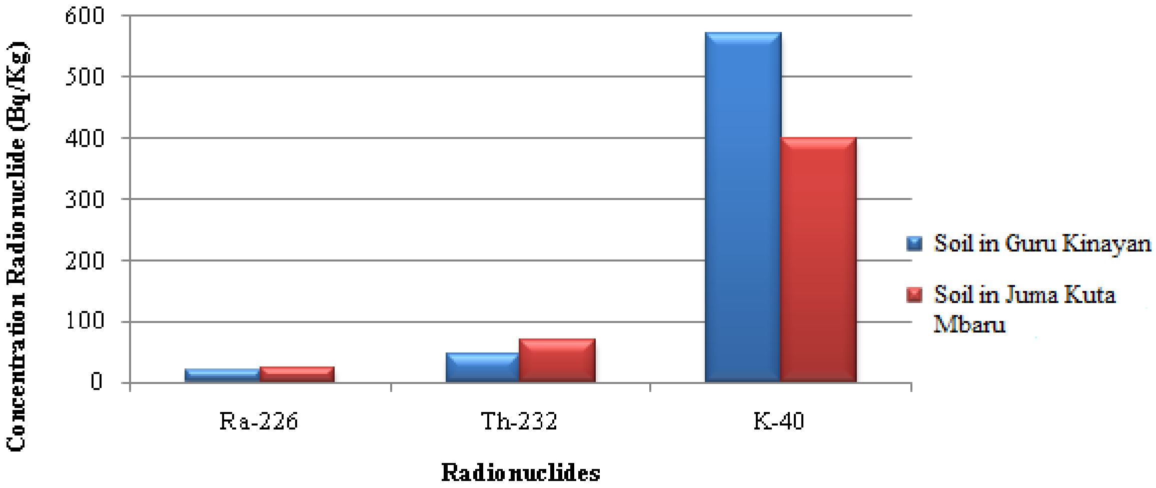

Figure 3 Radioactivity in soil

Table 2 shows that, the concentrations of ^{226}Ra and ^{232}Th in the plants food sample are undetectable and there is a very low ≤ 0.36 Bq/Kg less than the lowest detection limit. This means that value of ^{226}Ra and ^{232}Th in the crop sample very small. The concentration of ^{40}K radionuclides in this study ranged from 26.29 ± 1.28 Bq/Kg were found in the Juma Kuta Mbaru corn plant to the highest of 190.19 ± 5.08 Bq/Kg contained in cabbage Juma Kuta Mbaru samples. The concentration of the ^{40}K radionuclides is higher than the concentrations of ^{226}Ra and ^{232}Th, this may be due to the very small migration of Radium and Thorium from the soil to the plants surrounding the environment. Potassium is a macronutrient in plants so the concentration will definitely be higher. Soil characteristics can help the mobilization and migration of Potassium to all parts of the plant [9]. **Figure 4** shows the compare activity radionuclides in plants food between Guru Kinayan and Juma Kuta Mbaru.

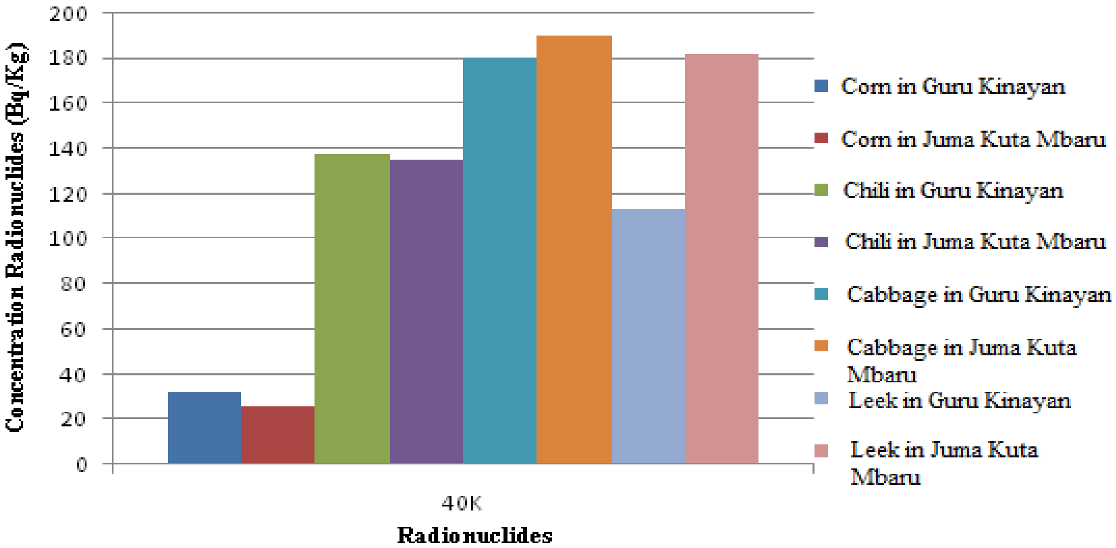

Figure 4 Radioactivity in plant food

Soil-to-plant transfer factors

The transfer factor values are used to assess the uptake of radionuclides by vegetation within the study area and compared to similar published values. The TF values of ^{226}Ra, ^{232}Th, and ^{40}K in crop plants are also outlined in **Table 3**. Transfer factor soil-plant was determined by using the following equation

$$FT = \frac{\text{Activity concentration of nuclide in plant crop}}{\text{Activity concentration of nuclide in dry soil}} \quad (3)$$

Table 3 Transfer factor soil-plants

Type of sample	**TF Value**		
	^{226}Ra	**^{232}Th**	**^{40}K**
Soil-corn in Guru Kinayan	Undetectable	Undetectable	0,057
Soil-chili in Guru Kinayan	Undetectable	Undetectable	0,242
Soil-cabbage in Guru Kinayan	Undetectable	Undetectable	0,316
Soil-leek in Guru Kinayan	Undetectable	Undetectable	0,199
Soi-corn in Juma Kuta Mbaru	Undetectable	Undetectable	0,066
Soil-chili in Juma Kuta Mbaru	Undetectable	Undetectable	0,340
Soil-cabbage in Juma Kuta Mbaru	Undetectable	Undetectable	0,478
Soil-leek in Juma Kuta Mbaru	Undetectable	Undetectable	0,458

Table 3 shows that, the transfer factor value on ^{40}K is higher than the transfer factor value of ^{226}Ra and ^{232}Th. This is due to the high concentrations of Potassium-40 in soil samples, thus providing a great opportunity for plants to absorb the ^{40}K element from the indispensable in soil in which the ^{40}K is the growth and fertility of the plant. Transfer factor values for ^{226}Ra and ^{232}Th were undetectable, this is because activity concentration of ^{226}Ra and ^{232}Th were under detection limit. **Figure 5** shows the compare transfer factor soil to plant between Guru Kinayan and Juma Kuta Mbaru.

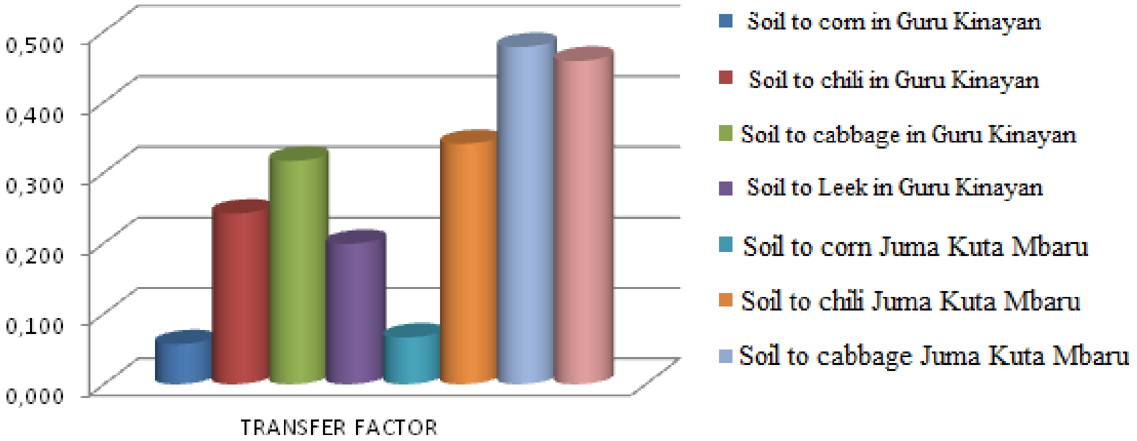

Figure 5 Transfer Factor Soil to Plant

Annual internal dose

Using the activity concentration results presented in Table 2, the annual effective internal dose due to the ingestion of ^{226}Ra, ^{232}Th and ^{40}K radionuclides are calculated. The results are given in **Table 4**.

Table 4 The estimated annual internal dose for ^{226}Ra, ^{232}Th and ^{40}K from plants crop

Type of sample	**Consumption rate (Kg/year)**	**Annual dose effective (mSv/year)**		
		^{226}Ra	**^{232}Th**	**^{40}K**
Corn in Guru Kinayan	4,53	Undetectable	Undetectable	0,0009
Chili in Guru Kinayan	1,58	Undetectable	Undetectable	0,0014
Cabbage in Guru Kinayan	2,59	Undetectable	Undetectable	0,0029
Leek in Guru Kinayan	-	Undetectable	Undetectable	-
Corn in Juma Kuta Mbaru	4,53	Undetectable	Undetectable	0,0007
Chili in Juma Kuta Mbaru	1,58	Undetectable	Undetectable	0,0013
Cabbage in Juma Kuta Mbaru	2,59	Undetectable	Undetectable	0,0031
Leek in Juma Kuta Mbaru	-	Undetectable	Undetectable	-
Total				0,0103

The total annual internal dose of ^{40}K in Karo region has the highest effective dose was estimated to be 0.0103 mSv/year compared with ^{226}Ra and ^{232}Th, this is because no detection and/or activity concentrations of ^{226}Ra and ^{232}Th were under detection limit in the sample. Thus the results of this study indicate that the total annual internal dose from ingestion of plant food sample was 0.0103 mSv/year. It can be seen that this doses is lower than annual dose limit of 1 mSv for general public [10].

Conclusion

The study on the activity concentration of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in some soil and food crops in Karo Region show that activity concentration of ^{40}K is highest than the others, this may be due to the very small migration of Radium and Thorium from the soil to the plants surrounding the environment. Potassium is a macronutrient in plants so the concentration will definitely be higher.

The transfer factor soil-plant show that value on ^{40}K is higher than the transfer factor value of ^{226}Ra and ^{232}Th. This is due to the high concentrations of Potassium-40 in soil samples, thus providing a great opportunity for plants to absorb the ^{40}K element from the indispensable in soil in which the ^{40}K is the growth and fertility of the plant.

Based on the activity concentration of radionuclides and data on food consumption rate, the annual internal dose received by general public living in Karo region area due to the consumption of the foodstuff is 0.0103 mSv/year. This dose is lower than annual dose limit of 1 mSv for general public.

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