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Natural radioactivity levels in agricultural soils in trans Nzoia county, Kenya

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ABSTRACT
Samples of soil were collected from the selected regions of agricultural activities in Trans – Nzoia county, Kenya. Three adjacent soil samples were mixed up from each sampling point to get twenty representative (composite) soil samples. The soil samples were dried at 1100C, grounded and sieved through a wire mesh of diameter 0.5 mm and packed in plastic beaker that were sealed to prevent leakage of radon. The soil samples were kept for 28 days for secular equilibrium to be reached between the activity of uranium, thorium and potassium, radium and their progeny. The activity concentration level for 232Th, 238U and 40K in soil samples were determined using gamma ray spectrometer with NaI (TI). The average activity concentration for 232Th, 238U and 40K was found to be 171±8.56 BqKg-1 with the range of 32±1.6 – 414 ± 20.73, 0.5±0.02 BqKg-1 with the range of 0.3±0.01-1.7±0.08 and 1059±52.96 BqKg-1 with the range of 301±15.07-1541±77.07 respectively. The average radium equivalent activity was found to be 326±16.3 BqKg-1 while external and internal hazard indices were found to be 0.8±0.04 and 0.8±0.04 respectively. These results reveal minimal significant radiological health hazards for inhabitants within the selected study areas.

KEYWORDS
agricultural; soil; natural radioactivity

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(1) INTRODUCTION

Gamma radiation from radionuclides with half-lives comparable to the age of the earth such as 40K and radionuclides from the progeny of 238U and 232Th series are the main contributors of external source of irradiation to human body. Of these naturally occurring radionuclide material (NORM), 40K is the most abundant and is found in earth's crust on average of 2.6%, while uranium and thorium are present in levels of parts per million (1). The nuclides existing in bedrock are weathered off; chemically or physically and through transportation are finally deposited in farms without rocks. Human activities like mining use of inorganic fertilizers in farming and processing increases the concentration both in end products or wastes to produce technologically enhanced naturally occurring radioactive material (TENORM). These radionuclides contribute to enhanced radiations exposure to human beings and animals (2).

Artificial radiations originate mainly from fallout resulting from the nuclear weapons trial, airborne release from nuclear establishments and reactor accidents (3). Radioactive dust is released into the atmosphere, carried widely and later fall gradually to the earth's surface or washed down in rain and eventually settles on land or in the sediments of water (2). There has been general concern by the general public on the increased pollution caused by radiations in the recent years. Some of the sources of these radiations are artificial or natural (4). According to the United Nations Scientific Committee on the effects of Atomic Radiations, there is the need for more data on the level of exposure from natural, manmade and occupational sources at the low levels (5). However, the hereditary effects of radiation on human population are still not fully quantified (5). Sources such as cosmic rays from outer space, terrestrial gamma-radiations and potassium – 40 are some of the main contributors to the radiation's doses exposed to human beings.

The assessment on the levels of radiations dose exposure to the world population is basically from natural radiation sources (UNSCEAR, 1988). Of the natural sources, cosmic radiations are common as they result from high energy cosmic rays' incident to the Earth's atmosphere and are therefore present everywhere in the environment (6). Radon is the main contributor of environmental radiation hence the leading in human radiation exposure (5)

The radionuclides can be absorbed in plants; main source of the food for humans and animals. They also spread to the environment through building materials sourced from areas with elevated levels of radioactivity or even infiltrate water sources such as rivers and streams that pass through such areas. The study of the radioactive components in soil is a major link in understanding the behavior of radioactivity in the ecosystem, because these materials emit radiation by the disintegration of natural radionuclides and contribute to the total absorbed dose via ingestion, inhalation and external irradiation (6). Soil acts as a source of continuous radiation exposure to humans and as a medium of migration for the transfer of radionuclides to the biological systems and causes radiological contamination in the environment. In addition to the natural sources, soil radioactivity is also affected by man– made activities. The sources of radioactivity in cultivated soils are mainly due to the extensive use of fertilizers, rich in phosphates, for agricultural purposes (7). The concentration of uranium and thorium are increased in environment due to these fertilizers. Usually, fertilizers are considered as a technologically enhanced source of natural radiation (7).

(2) MATERIALS AND METHODS

(2.1) Study area

Trans – Nzoia county located in the Western region of Kenya is characterized by large scale agricultural activities. It is located 7.41.41N, 7.01.20E and has an area of 2,469.9 km2 and a population of approximately 990,341. Figure 2.1 shows the map of Trans-Nzoia county.

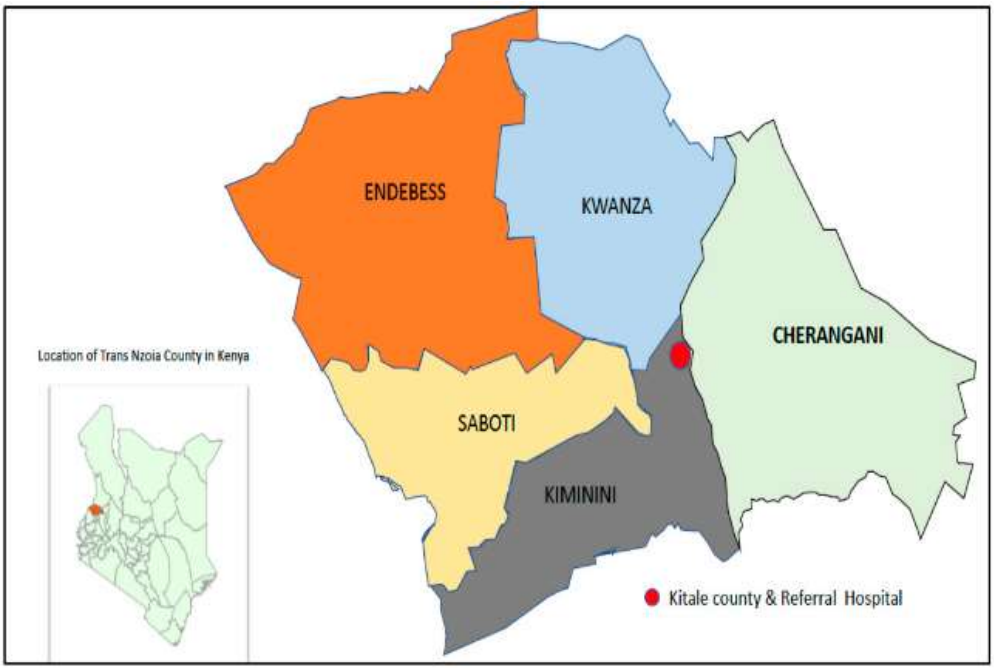

FIGURE 2.1: Map of Trans – Nzoia County

The surface soil samples were collected randomly from four sub counties of the Trans-Nzoia County: namely Endebes, Kiminini, Kwanza, Saboti and Cherangani.

(2.2) Collection of Soil Samples

Soil samples were sampled from points at a diameter of 2 m using 500 ml beakers. This improved the representativeness of the samples. The soil samples within the collection point were then mixed uniformly up to a depth of 50 cm using a spade; samples weighing 500 g were then collected, packed tightly into clean waterproof plastic bottles and then labelled. For example; the soil sample number was marked as S_{o1} meaning soil sample number 1, sample number 2 was marked as S_{o2} meaning soil sample number 2, sample number 3 was marked as S_{o3} meaning soil sample number 3 and so on, to cover the total number of twenty soil samples collected that is S_{o1}, S_{o2}, S_{o3} to S_{o19}.

(2.3) Sample preparation

To investigate natural radioactivity, twenty samples where be collected at depths of 0-30cm from maize farms and fallow areas across twenty sites. Each sample weighing approximately 500g and was considered the representative of the sampling sites. Each sample was packed into a plastic bag, labeled and carried to a laboratory. The samples were dried in an oven at 110°C for 24 hours to obtain a constant dry weight, which was used to determine moisture content. To retain constant grain size and obtain a fine-sized homogeneous soil sample for measurement, the powder was sieved through a 2 mm mesh wire (8). An approximate 200g sample of the homogeneous soils was packed and sealed in airtight beaker; after that, the sample was held for four weeks in an incubation process to allow for secular equilibrium between uranium and its progenies (9).

(2.4) Activity concentration

The activity concentration of the samples was calculated using equation 2.1 (10);

$$A_s M_s I_R = A_R M_R I_S \qquad (2.1)$$

Where M_R , A_s and I_R are the mass, activity concentration and intensity of specific radionuclide in the reference sample RGMIX respectively while are M_s and I_S the mass of the sample and intensity of the specific radionuclide in the sample under study respectively (11).

(2.5) External hazard index

The external radiation hazards index due to natural radionuclides of ^{226}Ra, ^{232}Th and ^{40}K were determined in terms of external or outdoor radiation hazard index. This index must be less than unit, in order to keep the radiation hazard insignificant. The external hazard index was calculated using equation 2.2 (12);

$$H_e = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (2.2)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K respectively.

(2.6) Internal hazard index

The internal hazard index originating from short lived radon was calculated using equation 2.3 (13);

$$H_i = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (2.3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K respectively (14).

(3) RESULTS AND DISCUSSION

(3.1) Activity concentration of naturally occurring radionuclides

The activity concentration of the three primordial radionuclides Uranium-238, Thorium-232 and Potassium-40 in soil samples from Trans-nzoia County was determined by equation 2.1. The average activity concentration of ^{238}U, ^{232}Th and ^{40}K were 0.5±0.02 Bqkg^{-1}, 171±8.56 Bqkg^{-1}, and 1059±52.96 Bqkg^{-1} respectively. The minimum activity concentration for ^{238} U, ^{232}Th and ^{40}K were found to be 0.3±0.01 Bqkg^{-1}, 32±1.6 Bqkg^{-1} and 301±15.07 Bqkg^{-1} while the maximum concentration values were 1.7±0.08 Bqkg^{-1}, 414±20.73 Bqkg^{-1} and 1541±77.07 Bqkg^{-1}respectively.

The high values in some samples were due to presence of granite, phosphate, sandstone and quartzite that were eroded from hills to spread non-uniformly on the farms (14).

The measured activity concentration of ^{40}K exceeds the values of both Uranium and thorium because it is the most abundant radioactive element under consideration. In addition, the excessive use of potassium-based fertilizers in agricultural activities to improve yields may have contributed to the higher value of ^{40}K activity concentration (10). The highest concentration of 414±20.73 Bqkg^{-1} of thorium is in the 19th samples is due the presence of rocks like shale, Hornblende-biotite gneiss abundant in this area. Table 3.1 shows the activity concentrations for the three natural radionuclides ^{238}U ^{232}Th, and ^{40}K in all the sampling site.

TABLE 3.1: Average Activity Concentration Values of the Selected Samples from Trans – Nzoia County, Kenya

	ACTIVITY CONCENTRATION (Bq/kg)		
RADIONUCLIDE	**40K**	**232Th**	**238U**
MAXIMUM	1541±77.07	414±20.73	1.7±0.08
MINIMUM	301±15.07	32±1.6	0.3±0.01
AVERAGE	1059±52.96	171±8.56	11±0.55

From Table 3.1, the average activity concentration for the collected soil samples was 0.5±0.02 Bqkg^{-1}, 171±8.56 Bqkg^{-1}, and 1059±52.96 Bqkg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively. The minimum activity concentration for ^{238} U, ^{232}Th and ^{40}K were found to be 0.3±0.01 Bqkg^{-1}, 32±1.6 Bqkg^{-1} and 301±15.07 Bqkg^{-1} while the maximum concentration values were 1.7±0.08 Bqkg^{-1}, 414±20.73 Bqkg^{-1} and 1541±77.07 Bqkg^{-1}respectively. The activity concentration of ^{40}K and ^{232}Th exceeded the world's average values of 400 Bq/kg and 45 Bq/kg respectively. The activity concentration of ^{238}U evaluated was lower than the world average of 33 Bq/kg (15).

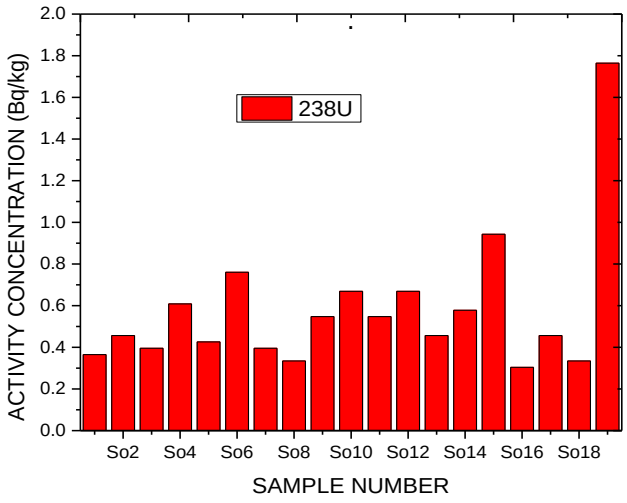

FIGURE 3.1: Bar Graph showing Activity Concentration of ^{238}U in the Soil Samples collected.

From Figure 3.1, the average activity concentration level of ^{238}U was 0.5±0.02 Bqkg^{-1}. The minimum activity concentration for ^{238} U was found to be 0.3±0.01 Bqkg^{-1} while the maximum concentration value was 1.7±0.08 Bqkg^{-1}. as shown in Figure 3.1. The variation in the activity concentrations in the soil samples varied with the sample location due to the geological formation and type of soil in the study area.

(3.2) Hazard Indices

The average value of external hazard index was found to be 0.3±0.01 with a minimum of 0.1±0 and a maximum value of 0.7±0.03 mSv/y.

The internal exposure to carcinogenic radon and their short-lived progeny is quantified by the internal hazard index which was found to be 0.5±0.02 with a minimum of 0.2±0.01. It was noted that the internal hazard index is higher than the external because of the short-lived radon is exhaled and concealed in room and thus increasing concentration.

(3.2.1) Internal Hazard Index

The evaluation of internal radiation hazard indices in the collected tailing samples was done using equation 2.3 (6). The average internal hazard index of 0.8±0.04 was obtained from the samples analyzed (Table 3.1). A plot shown in Figure 3.2 shows internal hazard indices of the collected soil samples.

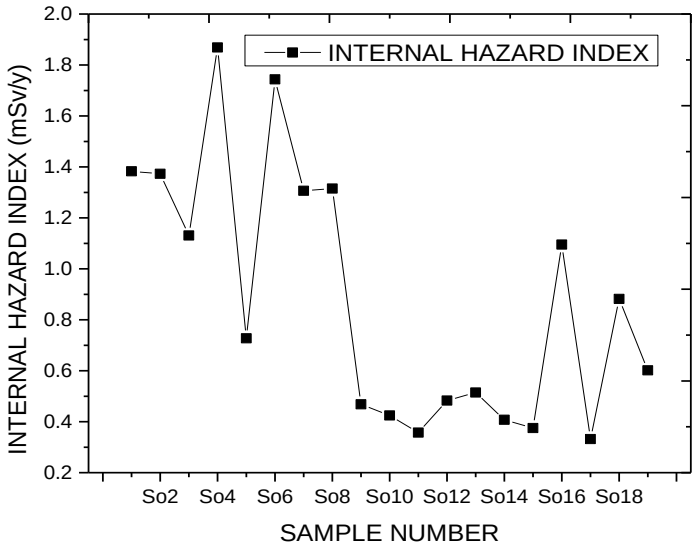

FIGURE 3.2: A Plot Showing Internal Hazard Index for the Soil Samples Collected

Based on the sample's individual hazard indices from Figure 3.2, soil from the study area does not pose a health hazard to the immediate population because the mean index for all samples studied was below the set limits of 1 (16). The maximum and minimum internal hazard indices for the collected soil samples were 1.7 ± 0.08 and 0.3 ± 0.01 respectively. Therefore, from the results obtained, it can be seen that all the values were less than the maximum recommended value hence do not pose any great danger to the population leaving within the study area

(3.2.2) External Hazard Index

The evaluation of this index from activities of twenty samples was computed using equation 2.2 (7). The overall mean H_{ex} in the samples collected was 0.8 ± 0.04 mSv/y which was below the permissible level of 1 unit (17). The individual external hazard indices for all the tailing samples were reported in Figure 3.3.

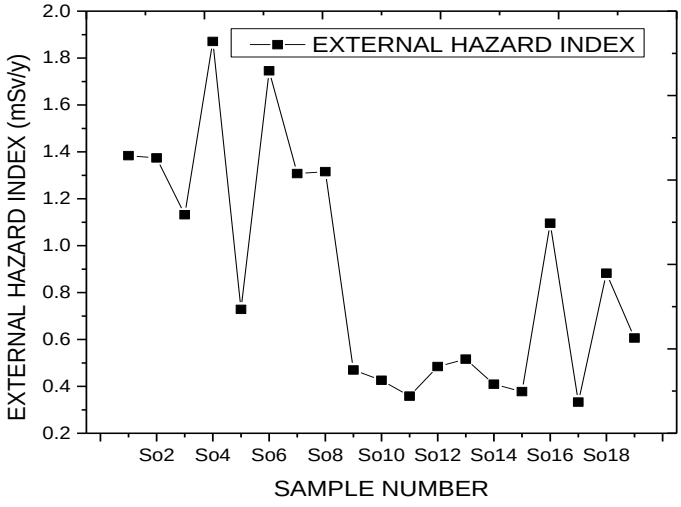

FIGURE 3.3: A-Line Graph Showing External Hazard Indices from the Soil Samples

From Figure 3.3, the minimum and maximum external hazard index were 0.3 ± 0.01 and 1.8± 0.09 respectively. Very few samples posted external hazard index above a unit while the rest of the samples were within the recommended limit. This was as a result of varying ^{40}K activity concentration and activity concentration of ^{238}U and ^{232}Th for the same samples was also higher compared to the other samples. This made their external hazard indices to be higher than a unit but still below the recommended exceptional value of 100 mSv/y hence posing no significant potential health threat to the miners and the general population (18).

CONCLUSION

Assessment of human exposure to natural source of radiation on the soil in Trans-Nzoia County has been determined using NaI (TI) gamma ray spectrometer. The results showed average activity concentration for ^{232}Th, ^{238}U and ^{40}K as 171±8.56 $Bqkg^{-1}$, 0.5±0.02 $Bqkg^{-1}$, and 1059±52.96 $Bqkg^{-1}$ respectively. The activity concentrations were also found to be higher than worldwide average values of 45 $Bqkg^{-1}$ and 420 $Bqkg^{-1}$ for ^{232}Th and ^{40}K respectively. The activity concentration levels in soil of Trans-Nzoia County for ^{232}Th and ^{40}K were higher than world average due to continuous use of inorganic fertilizers that introduce ^{232}Th and ^{40}K in the soil. The existing metamorphic and granite rocks around Cherangani and Mt. Elgon produce mineral salts containing ^{232}Th, ^{238}U and ^{40}K that are eroded and spread in agricultural lands thereby increasing the activity concentration on the upper parts of Trans-Nzoia county. Through the process of stone and sand harvesting, irrigation of agricultural crops during dry season, the mineral soils from rivers are introduced into the soil. The origin of river Nzoia and Kiminini in Cherangani hill and Mt Elgon that contain granitic and metamorphic rocks made from silica and phosphate that contain ^{232}Th, ^{238}U and ^{40}K. The average radium equivalent was found to be 326±16.3 $BqKg^{-1}$ that was still below the world permissible values of 370 Bq/kg. The internal and external hazard indices were found to be 0.8±0.04 and 0.8±0.04 respectively which is also less than the safety limit of 1 $mSvy^{-1}$. This indicates that the radiation hazard from naturally occurring radionuclides in soils of Trans-Nzoia County is insignificant but similar studies need to be repeated for different seasons to obtain consistent results on the seasonal effects on levels of radioactivity of Trans - Nzoia agricultural soil.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding publication of this article.

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