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. DETERMINATION OF HAZARDOUS LEVELS OF HARVESTED CONSTRUCTION SAND IN SELECTED RIVERS OF BUNGOMA COUNTY, KENYA

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ABSTRACT

The average activity concentration for the three primordial radioactive nuclides were; 2±0.1Bq/kg with a range of 0± 0.03Bq/kg to 4±0.24Bq/kg for ^{238}U, 55±2.78Bq/kg with a minimum value of 32±1.6Bq/kg and a maximum value of 87±4.38Bq/kg for ^{232}Th and 51±2,56Bq/kg with a minimum value of 27±1.37Bq/kg and a maximum value of 76±3.8Bq/kg for ^{40}K. The mean activity concentrations for ^{238}U and ^{40}K were below the world averages of 33Bq/kg and 420Bq/kg respectively. Radium equivalent varied from 6±0.32Bq/kg to 986±Bq/kg with an average value of 230±11.51Bq/kg. This was below the world's permissible value of 370Bq/kg. Internal and external hazard indices ranged between 0±0mSv/y to 2.6±0.13 mSv/y with a mean of 0.6±0.003mSv/y, 0±0 mSv/y to 2.6±0.13 mSv/y with a mean of 0.6±0.003mSv/y respectively. These radiological parameters show an insignificant radiological health risk associated with the harvesting and use of sand in construction from the selected rivers. This study is essential to the general and inhabitants of Bungoma County as they are able to know the risks associated by the use of sand from the selected reivers in Bungoma County.

1.0. INTRODUCTION

Radiation exposure is mainly through natural and artificial sources. The main radionuclides which are of concern are ^{238}U, ^{232}Th and ^{40}K and their progenies which are responsible for generation of external gamma radiation (1). External gamma radiations which arise from NORMs is widely distributed on the earth's surface and contributes to more than 50% to the collective radiation dose received by the world's population (2). Human activities such as use of fertilizers for agriculture, mining and milling, processing uranium ores and mineral sand and burning of fossil fuel may influence the level of NORMs in the environment (3) Indoor exposure to radiations is dependent on the resources used for building and also on how long one spends indoor (4). In a house that is made of various materials such as stones, sand, cement and concrete, activities concentration due to internal radiations from the radioactive nuclides are great but simultaneously protecting the building from outdoor radiation (5). The world's average activity concentration for ^{238}U, ^{232}Th and ^{40}K is 33 Bq/kg, 45Bq /kg and 420Bq/kg respectively (6).

Radon and Thoron are radioactive colorless and odorless gas found in the environment. Radon accounts for 55% of the total radiation exposure in the environment (7). Outdoor radon is not a major risk since they disperse easily in the environment as compared to indoor radon and thoron which is as a result of the use of uranium and thorium rich soils and rocks as materials used for building. This is because radon and thoron emanating from soils and rocks which is used as raw material for building is strapped in the house and accumulates to a high concentration especially in the houses that are not well ventilated. This therefore necessitates the monitoring of radon and thoron in houses in a bit to understand their levels so as to take necessary measurements as a result of their health risk concern (8).

Most of the materials oftenly deposited at the riverbed comprises of sand and gravel of various sizes which are very important materials when it comes to construction (9). Rivers deposits are used expansively as a main construction material, in building of residential and offices complexes (8). Researches have revealed that internal exposure to radiations is due to radiation from building materials hence need to establish the activity concentration of primordial radioactive nuclides in sediments, sand and soil samples in order to precisely assess health implications as a result of radiations to the general public. Acute radiation damages are the most protuberant in muscles with fast multiplying cells such as in epithelial surfaces of the skin or elementary tract (6). Damages to important cell components are as a result of ionization and free radicals fashioned by radiations. The death of the cells during the first division after irradiation is as a result damage to DNA. Hereditary supplies in cells can be destroyed however small the dosage is due to ionization as a result of radiations exposure leading to cancer so many years later after the radiations or results to inherited diseases to the lineage of the exposed persons and this leads to possibilities of developing some effects under some definite conditions. The severity of the effects is dependent on how much dose one has received. Continued exposure to radiations leads to adverse effects on living matter. This is because, it leads to ionizing effects that damages the normal working of the cells (4). Radiation of less energy impairs the DNA triggering the death of cells and mutagenesis. Great amount of radiations doses destroy cells whereas low doses change the genetic DNA code of cells irradiated leading to birth defects and cancer diseases such as skin cancer, bone cancer and leukemia (1).

2.0. MATERIAL AND METHODS

2.1. Study Area

Bungoma County has a total population of 1,670,570 of which 812,146 are males and 858,389 females as per 2019 census (10). The county covers an area of $2069 km^2$ and neighbors the republic of Uganda to the North West, Trans-Nzoia County to the north East and South East, and Busia county to the West and South West. Figure 3.1 show the map of Bungoma County.

***Figure 3.1*: The map of Bungoma county showing distribution of rivers**

The county stretches between latitudes 0.4213˚N and 1.1477˚N and longitudes 34.3627˚E and 35.0677˚E. The county has several rivers. This study considered the following rivers: rivers Malakisi, Kuywa, Khalaba, Teremi, Sosio, Nzoia, Kiminini Kibisi, Chwele and Toloso. A total of twenty samples were collected using random sampling from these rivers where three samples were obtained from each river. Each sample collected had a net weight of 500g. This area is considered for study because of numerous activities that takes place in this region ranging from sand harvesting, transportation of the harvested sand and small - scale irrigation along the rivers. These activities may pose risks of radiations to workers and therefore research had to be undertaken to determine the extent of risks associated to workers.

2.2. Samples Preparation

Sieving was be done on the samples to achieve uniformity on the size of the grains using a sieve of diameter 2mm. Samples were then dried up in an oven at a temperature of around 105℃ to do away with any dampness. Samples were crushed by the use of the mortar and pestle and every time the mortar and pestle were used for grinding, they were washed to ensure samples are not contaminated. Samples were then packed in 500ml containers which were labelled and referenced and tightly closed to avoid leakages. They were then kept for a period of around thirty days to allow for secular equilibrium between ^{226}Ra, ^{238}U, ^{232}Th and their daughter nuclides. Gamma ray spectrometer was used to determine the activity concentration of the radioactive nuclides in every sample for around 5000 minutes to increase the accuracy of radioactive measurements (11).

2.3. Measurement Techniques and Principles

Specific concentration of radionuclides in the samples was done using NaI(TI) gamma ray spectrometer. Calibrations were done before counting the detector. This was done counting using a standard point source which are ^{22}Na (1368.6keV), ^{133}Ba (356.1keV), ^{60}Co (1173.2 & 1332.5keV), ^{137}Cs (661.9keV) and ^{26}Ra (186.2keV) supplied by the International Atomic Energy Association (IAEA) (12). Each sample was put in a highly shielded Na I(Ti) detector and measured for a period of around 10hours. An inbuilt software was used in the analysis of each of the measured gamma ray spectrum.

2.4. Activity Concentration of the Radionuclides

The activity concentration ^{238}U was determined using the counts of ^{214}Pb and ^{214}Bi. ^{232}Th was calculated from the counts of ^{228}Ac & ^{212}Pb and finally the concentration of ^{40}K were established from the counts of 1460.83keV. Equation 2.1 shows the analytical equation used in determination of the specific radionuclide activity concentration in Bq/kg (12).

$$A_c = \frac{N_D}{P.n.m} \quad \text{...} \quad 2.1$$

Where N_D is the net count rate (cps); measured count rates minus background count rates, p is the gamma ray emission count probability (gamma ray yield), n is the absolute counting efficiency of the detector system, m is the mass of the sample.

2.5. Radium Equivalent (Ra_{eq})

Radium equivalent refers to the weighted sum of activities of ^{228}Ra, ^{232}Th and ^{40}K basing on the supposition that 1Bq/kg of ^{226}Ra, 0.7Bq/kg of ^{232}Th and 13Bq/kg of ^{40}K gives the similar gamma dose (13). Equation 2.2 shows the empirical relationship used for calculating the radium equivalent.

$$Ra_{eq} = C_{Ra} + 1.423C_{Th} + 0.077C_K \quad \text{..................} \quad 2.2$$

where, C_{Ra} , C_{Th} and C_K is the activity concentration of 226-Ra, 232-Th and 40-K respectively in the sand samples expressed in Bq/kg.

2.6. External Hazard Index (H_{ex})

External hazard index is the quantity used to assess the radiological stability of sand. External exposure occurs when a body comes in to contact with radiations of high energy. Radiations are considered to have a negligible hazardous effect to the population when the external hazard index is less than one (14). The external hazard index will be worked out using equation 2.3:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \text{.............................. } 2.3$$

Where; C_{Ra}, C_{Th} and C_K is the mean activity concentrations of radium, thorium and potassium respectively in Bq/kg.

2.7. Internal Hazard Index (H_{in})

This may result from ingestion of terrestrial radioactive nuclides through inhalation. Measures due to inhalation are majorly as a result of ^{238}U, ^{232}Th and ^{40}K radionuclides in sand used for construction. Internal hazard exposure to radon is given by the equation 2.4 (15);

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \text{................................... } 2.4$$

Where; C_{Ra}, C_{Th} and C_K is the activity concentrations of radium, thorium as well as potassium correspondingly in Bq/kg. For internal hazard index to have a minimal hazardous effect, the value of the index should be less than one (16).

3.0. RESULTS AND DISCUSSION

3.1. Specific Activity Concentration

Activity concentration levels of the samples varied from 0±0.03 Bq/kg to 4±0.24Bq/kg with average activity concentration of 2±0.1 Bq/kg for ^{238}U, 0±0.03 Bq/kg to 689±34.45 Bq/kg with average activity concentration of 123±6.19 Bq/kg for ^{232}Th and 0±0.03 Bq/kg to 544±27.21 Bq/kg with an average activity concentration of 148±7.42 Bq/kg for ^{40}K. The activity concentration of ^{232}Th exceeded the world agreed average value of 45 Bq/kg while the activity concentration of ^{238}U and ^{40}K were below the world agreed averages of 33 Bq/kg and 400 Bq/kg respectively (17). The mean activity of ^{40}K was generally higher than ^{238}U and ^{232}Th for all the collected samples which are a common behaviour in the crustal contents. High potassium levels were attributed to the presence of minerals such as potash feldspar like orthoclase, micas like biotite (17). Figure 3.1 shows the activity concentration of ^{40}K in the selected samples

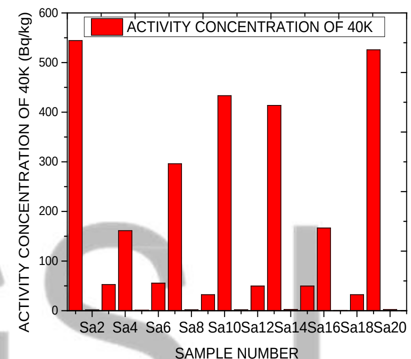

Figure 3.1 **A bar Graph Showing Activity Concentration of ^{40}K in the Collected Samples.**

From figure 3.1, the activity levels of ^{40}K ranged from 0±0.03Bq/kg to 544±27.21 Bq/kg with an average of 148±7.42 Bq/kg, 0±0.03 Bq/kg to 689±34.45 Bq/kg with an average activity of 123±6.19 Bq/kg for ^{232}Th. The results indicate a great variation in the mean activity level of the analyzed naturally occurring radionuclides ^{40}K in the sand samples. The variation in the activity concentrations in the sand samples varied with the sample location due to the geological formation and type of rocks across the selected rivers. Generally, the activity concentration of ^{40}K was higher than those of ^{232}Th and ^{238}U. This is because sand has high silica content which leads to the formation of silicate (SiO_2) during the process of cooling and solidification of igneous rocks where ^{40}K is highly compatible with silica than ^{232}Th and ^{238}U. Activity concentration of the primordial radionuclides in this study have been compared to the world averages as presented in table 3.1

Table 3.1: Mean activity concentration of sand measured in this study compared to the world average (18)

Radionuclide	Current study in $Bqkg^{-1}$	World average in Bq/kg^{-1}
^{238}U	2±0.1	33
^{232}Th	55±2.78	45
^{40}K	366±18.34	420

The mean activity concentration of the three radionuclides in the collected samples were below the world average agreed values hence harvesting of sand in the selected Bungoma County rivers has minimal radiological health threat to the population.

3.2. Radium Equivalent

Radium equivalent activity for the 20 samples collected from the selected rivers of Bungoma County had the lowest value as 6±0.32Bq/kg and the highest value as 986±49.31Bq/kg with the average of 230±11.51Bq/kg. This mean exceeded the world average of 89Bq/kg and below the permissible levels of 370Bq/kg (19). Figure 3.2 shows the determined radium equivalent from the selected samples from the study area.

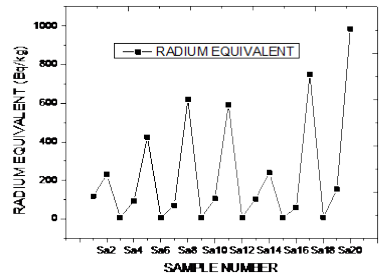

***Figure 3.2*: Radium Equivalent of the Samples Collected from the Selected Rivers.**

Apart from samples 5, 8, 11, 17 and 20, none of the other samples recorded a higher value 370Bq/kg as shown in figure 5.6. This is attributed to the fact that these rivers flow on the bed rocks that are rich in radioactive igneous rocks as most of these river's flow from a same source which is mount Elgon (14). The hazard indices associated with sand used for construction in the studied area in comparison with hazard indices of sand used for construction reported from other regions is shown in table 3.2

Table 3.2: Radium equivalent, gamma representative index, I_γ, external hazard index and internal hazard index obtained in this study as compared with other surveys in Kenya.

COUNTRY	Ra_{eq} (Bq/kg)	Hex(mSv/y)	Hin (mSv/y)	REFERENCES
Kenya	256	0.69	0.95	12
Kenya	327	0.72	0.98	17
This work	230	0.6	0.6	

3.3. Hazard Indices

Hazardous internal exposure to human respiratory system is due to inhalation of radioactive gases. Internal hazard index was found to have a minimum value of 0±0 mSv/y and a maximum value of 2.6±0.13mSv/y with a mean of 0.6±0.03mSv/y. This value is higher as compared to the world average of

0.42mSv/y. Figure 3.3 shows a graph of internal hazard index for the 20 sampling sites.

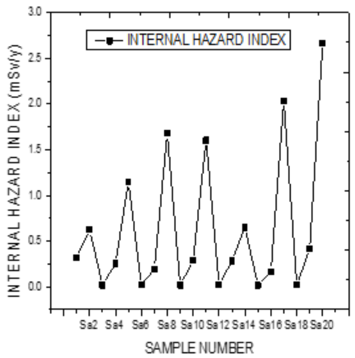

***Figure 3.3*: Internal Hazard Index of the Collected Samples**

External exposure of humanity to direct gamma radiation is measured by getting the external hazard index. Values of external hazard index ranged between 0±0 mSv/y to 2.6±0.13mSv/y with an average of 0.6±0.03mSv/y which was still below the criterion levels of 100 mSv/y (20). Figure 3.4 shows a graph of external hazard index for the values collected for the 20 sampling sites

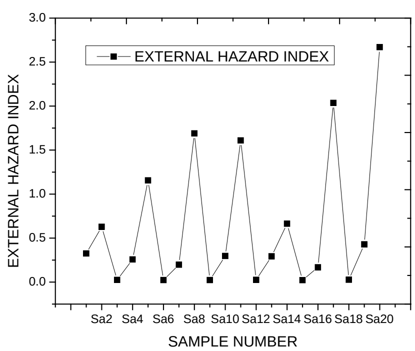

***Figure 3.4*: External Hazard Index of the Analyzed Samples.**

A few of the samples recorded external hazard index which had a value which is above the world recommended average of 1mSv/y as shown in figure 5.7. minimum exposure is witnessed on samples a, Sa_6, Sa_9, Sa_{12}, Sa_{15}, and Sa_{18}. These samples were collected on rivers Kamukuywa, Khalaba, Kiminini, Kibisi, Toloso and Kuywa while maximum value was recorded on Sa_{20} which was collected on river Nzoia (21). This shows that sand extracted from majority of the selected rivers of Bungoma County is safe for use in construction and other purposes without posing any radiological risk. Even though all the sand samples pose no significant threat on the basis of acceptable limits, sand from river Nzoia may be hazardous especially if the time of exposure (occupancy) is higher than the o ne used in this work.

CONCLUSION

The average activity concentration for ^{238}U, ^{232}Th and ^{40}K obtained in this study were as follows; 2±0.1 Bq/kg with the range of 0±0.03Bq/kg, 55± 2.78 Bq/kg with the range of 32±1.6Bq/kg to 55±2.78Bq/kg and 366± 18.34Bq/kg with the range of 27±1.137Bq/kg to 51±2.56Bq/kg respectively. Generally, the activity concentration of ^{238}U was less than the world recommended value of 33Bq/kg (UNSCEAR, 2008). The radium equivalent average value was found to be 230±11.51 Bq/kg which is below the world average of 370Bqkg^{-1}. The internal hazard index and external hazard index for all the samples collected both recorded value of 0.6±0.03 mSv/y which was less than a unit. Therefore, sand harvested in the selected rivers of Bungoma County are recommended to be used as building materials since the radiological parameters do not exceed any criterion level.

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CONFLICT OF INTEREST

The authors have no conflict of interest in regard to the publication of this article

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