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RESEARCH ARTICLE OPEN ACCESS

MEASUREMENT OF RADIOLOGICAL PARAMETERS IN HARVESTED SAND IN BUNGOMA COUNTY RIVERS, KENYA

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ABSTRACT

Samples of sand were collected along the course of ten selected rivers two from each river through random sampling. Activity concentration of ^{238}U, ^{232}Th and ^{40}K were measured using high resolution NaI(Ti) gamma ray spectrometer. Activity concentration of the three primordial radionuclides obtained were used to calculate, absorbed dose rate, annual effective dose rate, interna and external hazard indices and radium equivalent. 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. The indoor and outdoor annual effective dose rate varied from 0±0mSv/y to 0.2±0.01mSv/y with an average of 0.1±0 mSv/y and 0±0.003mSv/y to 0.1±0.009mSv/y with a mean of 0.1±0.006 mSv/y respectively. The annual effective dose rates were below the safe limits of 1mSv/y. Therefore, use of sand from the selected rivers in Bungoma County, Kenya for construction has minimal health risks to the inhabitants.

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I. INTRODUCTION

Radioactivity as a result of natural sources is prevalent in man's immediate settings i.e from land, as a result of cosmic rays or as a result of indoor radiations from materials used for construction [1]. Studies have revealed that existence of sources of natural radioactivity such as ^{226}Ra, ^{232}Th and their daughter nuclides and ^{40}K in materials used for construction results in to detrimental internal and external effects to inhabitants. Radioactive nuclides (^{226}Ra, ^{232}Th and ^{40}K) are not evenly concentrated and spread in rocks and soils [2]. They are different on the basis of where they are obtained. Sediments that find their ways in to the rivers are products of disintegration of rock sediments (sand and silts) and erosion of soils and rocks. The natural radioactive nuclides concentration in the soils and rocks affects the radioactivity levels of the sediments of the river sediments.

Radiation exposure to human beings can be as a result of radiations coming from direct from the natural radioactive nuclides or internally as a result of inhalation from radon. [3]. Radon and its products of decay in air are chief suppliers of exposure to human from primordial sources [4]. Radon is the product of decay of natural radioactive nuclides ^{238}U, ^{232}Th and ^{235}U that are found in the earth's crust. Once Radon is formed, it may be released in the atmosphere depending on the rocks type, soil structure, amount of water present and weather-related factors [5]. Radon in houses is as a result of trapped radium present in the mineral particles that are used for construction. Materials used for building have certain level of natural radioactivity especially those that are obtained from radioactive nuclides of ^{238}U, ^{232}Th and ^{40}K [6].

According to UNSCEAR, 2000, the worldwide average value of outdoor gamma absorbed dose rate in air due to terrestrial sources is 54nGy/h and absorbed dose rate in air inside homes is usually higher the outside (20% on average, but sometimes much

more) due to the contribution of materials used for construction [7]. Natural radionuclides contribute to radiation exposure in two ways; external and internal exposure. External exposure comes mostly from direct gamma radiation emitted from the decay of the radionuclides of ^{238}U series. Internal exposure is due to alpha particles resulting from the decay of ^{222}Rn and its progeny. Radon is a chemically inert gas which is colorless, odorless and highly radioactive. When inhaled, the alpha particles are directly delivered in the tissues, creating a potential for radiogenic lung cancer.

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. 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. 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 [8] Indoor exposure to radiations is dependent on the resources used for building and also on how long one spends indoor [9]. 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 [6]. The world's average activity concentration for ^{238}U, ^{232}Th and ^{40}K is 33 Bq/kg, 45Bq /kg and 420Bq/kg respectively [10].

II. MATERIALS AND METHODS

II.1 STUDY AREA

The study was done in Bungoma County which is found in the Western region of Kenya. Bungoma County has a total population of 1,670,570 of which 812,146 are males and 858,389 females as per 2019 census [11]. The county covers an area of 2069km^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. 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 thirty 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 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. Figure 1 show the map of Bungoma County.

Figure 1: The map of Bungoma county showing distribution of rivers.
Source: [11].

II.2 COLLECTION OF SAMPLES AND PREPARATION

Two samples were collected from rivers listed above either upstream, in the course of the river or downstream when the river almost exit the county at accessible points where sand harvesting is done. A total of twenty samples were considered for study. Sand was scooped from the river using a shovel. The point at which sand samples was taken was determined by the use of a phone with GPS and then recorded. Samples obtained were put in plastic containers and labelling done depending on the position from which the sample was taken from. 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 [12].

II.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 using standard point sources 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) [13]. Each sample was put in a highly shielded Na I(Ti) detector and measured for a period of around 10 hours. An inbuilt software was used in the analysis of each of the measured gamma ray spectrum.

II.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 1 shows the analytical equation used in determination of the specific radionuclide activity concentration in Bq/kg [14].

$$A_c = \frac{N_D}{P.n.m} \quad (1)$$

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.

II.5 ESTIMATION OF ABSORBED DOSE RATE

Absorption dose rate refers to the energy that is put in an absorbing channel those radiations that cause ionization per unit mass. This quantity was determined from activity concentration of ^{238}U, ^{232}Th ^{40}K using the activity concentration-dose (nGy^{-1} per Bq/kg) conversion factor 0.462, 0.622 and 0.0432 respectively [4]. Equation 2 shows how to calculate the dose rate:

$$ADR\ (nGyh^{-1}) = 0.427A_U + 0.622A_{Th} + 0.043A_K \quad (2)$$

Where A_U, A_{Th} and A_K is the average activity concentration of ^{238}U, ^{232}Th and ^{40}K in Bq/kg respectively in the sand samples.

II.6 ANNUAL EFFECTIVE DOSE RATE (AED)

The factor 0.7Sy/Gy was used in estimating the effective dose rate received by the inhabitants due to radioactivity in sand. It was presumed that adults spend 80% indoor while 20% outdoor. In this research thus, the indoor and the outdoor level of occupancy were given as 0.8 and 0.2 correspondingly [4]. The indoor effective dose as well as the outdoor annual effective dose rates received by the population was calculated using the equation 3 and 4:

$$E_{in}(msvy^{-1}) = ADR(nGyh^{-1}) \times 8760(hy^{-1}) \times 0.8 \times 0.7(SvGy^{-1} \times 10^{-6}) \quad (3)$$

$$E_{out}(msvy^{-1}) = ADR\ (nGyh^{-1}) \times 8760(hy^{-1}) \times 0.2 \times 0.7(SvGy^{-1} \times 10^{-6}) \quad (4)$$

Where E_{in} and E_{out} is the effective dose rates for both the internal and external environments [15].

III. RESULTS AND DISCUSSIONS

III.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±0.1Bq/kg for ^{238}U, 32±1.6Bq/kg to 87±4.38Bq/kg with average activity concentration of 55±12.78Bq/kg ^{232}Th and 161±8.05Bq/kg to 689±34,45Bq/kg with an average activity concentration of 366±18.34Bq/kg for ^{40}K. The activity concentration of ^{232}Th exceeded the world agreed average value of 45Bq/kg while the activity concentration of ^{238}U and ^{40}K were below the world agreed averages of 33Bq/kg and 400Bq/kg respectively [16].

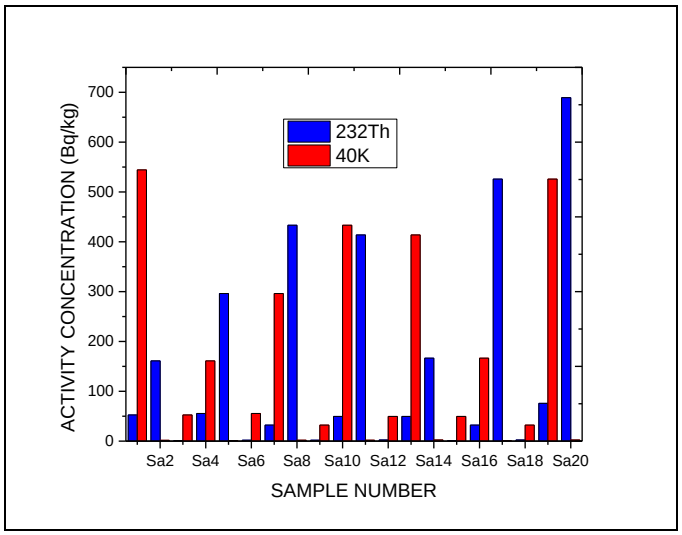

Figure 2: A Comparative Bar Graph Showing Activity Concentration of ^{232}Th and ^{40}K in the Collected Samples. Source: Authors, (2021).

From figure 2, the activity levels of ^{40}K ranged from 161 ± 8.05 Bq/kg to 689 ± 34.45 Bq/kg with an average of 366 ± 18.34 Bq/kg, 32 ± 1.6 Bq/kg to 87 ± 4.38 Bq/kg with an average activity of 55 ± 2.78 Bq/kg for ^{232}Th as shown in Figure 5.1. The results indicate a great variation in the mean activity level of the analyzed naturally occurring radionuclides (^{40}K and ^{232}Th) 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. The mean activity of ^{40}K was generally higher than ^{238}U and ^{232}Th for all the collected samples which are a common behavior in the crustal contents. Since the findings of activity concentration of ^{40}K, ^{232}Th and ^{238}U reported from the collected sand samples were far below the exemption levels of 1000 Bq/kg for both ^{232}Th and ^{238}U and 100,000 Bq/kg for ^{40}K [17], harvesting of sand in the selected rivers of Bungoma County has no potential health threat to the local population.

III.2 ABSORBED DOSE RATE

The mean absorbed dose rates for sand samples was 51±2.56nGyh^{-1} with the range between 27±1.37nGyh^{-1} and 76±3.81nGyh^{-1}. This is below the world averages of 60nGyh^{-1} [18]. Figure 3 shows a graph of absorbed dose rate against the sampling sites.

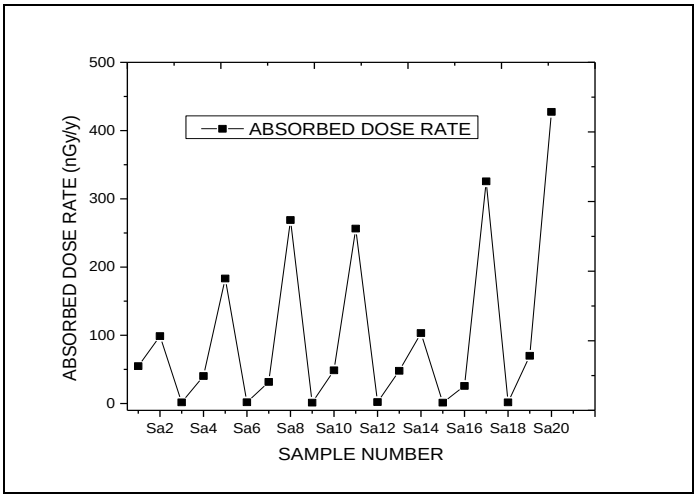

Figure 3: A Line Graph Showing Absorbed Dosed Rate for the Collected Samples.
Source: Authors, (2021).

Most samples recorded a mean which was below the world's average of 60nGyh^{-1}[19]. This could be attributed to the fact that most of these rivers do not flow in areas which are not rich in radioactive substances.

III.3 ANNUAL EFFECTIVE DOSE RATE (AEDR)

To evaluate the radiological risks of exposure, absorbed dose rates were converted to annual effective dose rates which is a reliable representation of the likely health effects to the general population. Table 1 shows the annual effective dose rate of the primordial radionuclides for the samples considered in this study.

Table 1: Annual Effective Dose rate values of the sampled Sand in selected Bungoma County, Kenya Rivers.

	AED_{in}(mSv/y)	AED_{out}(mSv/y)
MAXIMUM	0.2±0.01	0.1±0.009
MINIMUM	0.1±0	0±0.003
AVERAGE	0.1±0	0.1±0.006

Source: Authors, (2021).

Annual effective dose rate due to indoor exposure ranged from 0.1±0 mSvy^{-1} to 0.2±0.01 mSvy^{-1} with a mean of 0.1±0 mSvy^{-1} while the annual effective dose rate due to outdoor exposure varied from 0±0.003mSvy^{-1} to 0.1±0.009 mSvy^{-1} with a mean of 0.1±0.006 mSvy^{-1}. All the annual effective dose values were below the permissible limit of 1mSv/y [17]. Hence the sand harvested in the selected rivers in Bungoma County, Kenya has minimal health risk to the population.

IV. CONCLUSSIONS

Analysis of radioactivity levels in sand in the primordial radionuclides (^{238}U, ^{232}Th and ^{40}K) and their radiation hazards due to sand harvested in the selected rivers of Bungoma County has been determined using NaI(Ti) gamma ray spectrometer. The results obtained were compared with the recommended limits to assess whether sand samples pose any radiological threat to the harvesters and the dwellers of the houses. The average activity concentration for ^{238}U, ^{232}Th and ^{40}K that were obtained 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 absorbed dose rate had an arithmetic mean of 51±2.56 nGyh^{-1} which was below the world average value of 60nGyh^{-1} The annual effective dose rate had an average of 0.1± 0 mSvy^{-1}. This value was below the world average of 0.48 mSvy^{-1} and below the acceptable limit of 1mSvy^{-1}. The use of the harvested sand from the selected rivers in Bungoma County has minimal health risk to the population. Future measurement and analysis of natural radioactivity levels in water (wells, ponds, dams and rivers) and crops around the selected rivers should be carried to determine trends in radioactivity levels.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Lazarus Sindani, Michael Nakitare Waswa and Francis Maingi.
Methodology: Lazarus Sindani and Conrad Khisa Wanyama.
Investigation: Lazarus Sindani and Conrad Khisa Wanyama.
Discussion of results: Lazarus Sindani, Michael Nakitare Waswa, Francis Maingi and Conrad Khisa Wanyama.
Writing – Original Draft: Lazarus Sindani.
Writing – Review and Editing: Lazarus Sindani and Michael Nakitare Waswa.
Resources: Lazarus Sindani and Conrad Khisa Wanyama.
Supervision: Michael Nakitare Waswa and Francis Maingi.
Approval of the final text: Lazarus Sindani, Michael Nakitare Waswa, Francis Maingi and Conrad Khisa Wanyama.

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VII. CONFLICT OF INTEREST

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

VIII. REFERENCES

[1] Shikali, N, C. (2013). Radionuclide content of sand used for construction in kakamega County and associated indoor radon diffusion.

[2] Xwinel, L., & Zhang, X. (2008). Natural radioactivity measurements in rock samples of Cuihua mountain national geological park, China. *Radiation protection dosimetry*, 128(1), 77-82.

[3] Ngachin, M., Garavaglia, M., Giovani, C., Njock, M. K., & Noureddine, A. (2007). *Assessment of natural radioactivity & associated radiation hazard in some Cameroonian building materials. Radiation measurements*, 42(1), 61-67.

[4] UNSCEAR (2000). Sources, Effects and risks of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. Exposures from Natural Sources, 2000 report to the General Assembly, *Annex B, New York.*

[5] UNSCEAR, 1993: Exposure from natural sources of radiation, in United Nations Scientific Committee on the Effects of atomic Radiation, *United Nations*: New York.

[6] European Commission, EC 1999: Radiation Protection Principles concerning the natural Radioactivity of Building Materials, Directorate- General environment, nuclear safety and civil protection.

[7] Oyeyemi, K. D., Usikalu, R., Aizebeokhai, A. P., Achuka, J.A., & Jonathan, O. (2017, May). Measurements of Radioactivity levels in part of sOta Southwestern Nigeria: implications for radiological hazards ondices and excess lifetime cancer-risks. *In journal of physics: Conference series (vol. 852, No. 1, p.012042). IOP publishing.*

[8] Matsitsi, S. M., Linturi, J. M., Kebwaro, J. M., & Maweu, O.M. (2019). Effects of seasonal change on the levels of Geogenic Radionuclides in sand and rocks from Tyaa river deposits in Kitui county: Geophysics. *International Journal of Fundamental Physical Science*, 9(1), 14-19.

[9] Kamunde, K. B. (2016). *Radi ation exposure levels associated with construction* sand from Tharaka- Nithi County, Kenya.

[10] UNSCEAR (2008). UNSCEAR 2008 Report vol.1: *Sources of Ionizing Radiation*.

[11] Kenya National Bureau of Statistics, 2019. Population of Bungoma County retrieved from en.m.wikipedia.org>wiki>Bungoma-county.

[12] Tzortzis, M., Tsertos, H., Christofides, S., & Christoduolides, G. (2003). Gamma-ray measurements of naturally occurring radioactive samples from Cyprus characteristics geological rocks. *Radiation measurements, 37(3), 221-229.*

[13] Odongo, W. O. G., Hashim, N., & Chege, M. W (2021). Gamma Ray Spectrometric Analysis of Sand Samples from mSelected Beaches along Kenyan Coastline. *The scientific world journal, 2021*.

[14] Ebaid, Y. Y (2010). Use of Gamma Ray Spectrometry for Uranium isotopic Analysis of Environmental Samples. *Rom J phys 55(1-2): 69-74.*

[15] Tsai, T., Lin C., Wang, T. and Chu, T (2008). Radioactivity concentrations and dose Assessment for Soil Samples around nuclear power plant IV in Taiwan. *Journal of Radiological Protection, 347:347-360.*

[16] UNSCEAR. (2010). Sources and effects of ionizing radiation. Report to the General Assembly, with scientific annexes. New York: United Nations.

[17] ICRP. (2015). Occupational Intakes of Radionuclides: Part 1. (Oxford Pentagon press: ICRP; Publication) 130.

[18] United Nations Scientific Committee on the Effects of Atomic Radiation (2017). Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation. (UNSCEAR) 2016 Report, *Report the general sAssembly, with Scientific Annexes United Nations.*

[19] UNSCEAR, (2008). United Nations Scientific Committee on the effects of atomic radiation, sources, and effects of ionizing radiation. Report to General Assembly, with Scientific Annexes United Nations. United Nations, New York.