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Assessment of Natural Radionuclides in the Top Soil Sample of Ahero Fields, Kenya

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***Abstract*: A total of 17 soil samples of Ahero fields were collected at a depth of 15 – 20 cm; five samples each of mass 170g were collected from field 1, 2, 3 and two samples from field 4. The field 1 was where rice seedlings were already transplanted, field 2 was one in which transplanting was being done, field 3 was one in which rice had been harvested and the field had just been ploughed while field 4 was a field in which farming had not been done for two years. The activity concentrations were measured, identified and detected using NaI(Ti) detector that were used in calculation of Radium Equivalent, External Hazard Indices and Internal Hazard Indices. The average radium equivalent were 185.82 ± 7.04 Bq/kg, 119.19 ± 5.95 Bq/kg, 168.78 ± 8.44 Bq/kg and 208.81 ± 10.44 Bq/kg for fields 1, 2, 3 and 4 respectively. The average internal hazard index was 0.50 ± 0.02 mSv/y, 0.32± 0.01 mSv/y, 0.45 ± 0.03 mSv/y and 0.57± 0.03 mSv/y for fields 1, 2, 3 and 4 respectively. On the other hand, the average external hazard indices for the fields were 0.59 ± 0.02 mSv/y, 0.37± 0.01 mSv/y, 0.54± 0.02 mSv/y and 0.65± 0.03 mSv/y for fields 1, 2, 3 and 4 respectively. Generally, the results from the study indicate that the radiological health risk associated with the top soils of the study area is insignificant.**

***Keywords*: Ahero fields, Radium equivalent, External hazard index, Internal hazard index.**

1. Introduction

The existence of naturally occurring radionuclides of ^{238}U, ^{232}Th and ^{40}K can be traced back to the formation of the earth [1]. These radionuclides are found in significant amounts in soils and water depending on the geological, geographical location of the place and geochemical processes involved in the formation of the rocks [2], [3]. The largest percentage of exposure to the human population is due to primordial radionuclides [4] while terrestrial radiation is as a result of emissions from the radionuclides of ^{238}U and ^{232}Th and their progeny but ^{40}K exists as a singly occurring natural radionuclide which also emits gamma radiation [5].

Agricultural practices such as use of inorganic fertilizers to replenish both macro and micro nutrients to the soil continuously adds to the radioactivity levels of the soils [6]. These radionuclides accumulate in the soils and are taken up by the plant through the roots to the grains for the case of rice and eventually into the human body organs through the ingestion process [7]. The radionuclides of ^{238}U and ^{232}Th are highly radiotoxic; thus, they may cause clinical effects in the human body including damage to the kidney [8]. It is worth noting that human exposure through the ingestion of these radionuclides is a worldwide issue [9].

This study focused on the assessment of Ahero fields in order to ascertain the safeness of these soils to farmers and the general public.

2. Materials and Methods

A. Study Area

The route map of Ahero paddy fields that are under the Ahero irrigation scheme is as shown in figure 1.

Fig. 1. Map showing Ahero irrigation scheme

This study was conducted in Ahero fields of Kisumu County, Kenya. The source of water for irrigation in these fields is from River Nyando [10]. The soil in this region has low percolation rates and hence makes them suitable for cultivation of rice [11]. The geology of Nyando wetlands of which Ahero paddy fields forms part are characterized by pre- Cambrian system of granodiorites, tertiary and quaternary volanics i.e., granites, ryolites and phonolites and also metamorphic formations [12].

B. Sample Collection and Preparation

A total of 17 top soil samples each of mass 170g were collected from the study area. Five samples were collected from the fields 1, 2, 3 and two samples from field 4 at a depth of 15-

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20 cm. The samples were then taken to the laboratory and spread on mats properly labeled to avoid mix up for two weeks to dry. The dry samples were then crushed using mortar and pestle then sieved through a 2.00mm mesh (< 2.00 mm particles were used) then hermitically sealed in labeled containers for a period of 30 days for the radionuclides to attain a secular equilibrium between the parent and daughter radionuclides before being taken for gamma ray spectroscopy.

C. Gamma Ray Spectroscopy

Each soil sample was placed in a NaI(Ti) gamma ray spectrometer for a period of 30000 seconds for measurement of the radionuclides including their detection and identification. The calibration of the detector was done using certified samples from IAEA. The peaks corresponding to 1765 Kev was considered for ^{238}U, 2615 Kev for ^{232}Th and 1460 Kev for ^{40}K.

As the gamma rays from the sample strikes the NaI(Ti) crystal, photons are dislodged from the photocathode that are multiplied in the photomultiplier tube. The charges produced are collected by the pre- amplifier attached to the detector whose pulses are increased in size by the amplifier. The multichannel analyzer then digitized the pulses and displayed them through the personal computer.

3. Results and Discussions

A. Activity Concentrations of the Radionuclides

The activity concentrations of the radionuclides were obtained from the research done by Mukanda et al 2022 [13] at same study area.

B. Calculation of Radium Equivalent (Ra_{eq})

Radium equivalent is the gamma output from the three radionuclides described by a single value [2] and since the distribution of the three radionuclides is not the same, it was evaluated using equation 1 [14],

$$\mathrm{Ra_{eq}} = \mathrm{A_u} + 1.43\mathrm{A_{Th}} + 0.077_{\mathrm{k}} \quad (1)$$

Where A_u, A_{Th} and A_k are activity concentrations of ^{238}U, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. The radium equivalent values of the samples were put in table 1.

The average radium equivalent values were found as 185.82 ± 7.04 Bq/kg, 119.19 ± 5.95 Bq/kg, 168.78 ± 8.44 Bq/kg and 208.81 ± 10.44 Bq/kg for fields 1, 2, 3 and 4 respectively. It can be noted from the average values that the values are not the same because the activity concentrations for the samples from the various fields were also different. All the fields however had their values below the world permissible limit of 370 Bq/kg [15].

The radium equivalent values for the various samples in this study was represented in figure 2.

C. Estimation of External Hazard Indices (H_{ex})

The external hazard indices were calculated to account for the external exposure of the radiation resulting from direct gamma radiation emanating from the three radionuclides using equation 2 [15].

$$H_{ex} = \frac{A_u}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (2)$$

Where A_u, A_{Th} and A_k are activity concentrations of ^{238}U, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively.

Table 1
Ra_{eq} for all the samples in this study

	Sample	Radium Equivalent (Ra_{eq}) Bq/kg
Field 1	S_1	225.02 ± 0.00
	S_2	154.88 ± 7.74
	S_3	296.83 ± 14.84
	S_4	122.26 ± 6.11
	S_5	130.10 ± 6.50
	Average	$\mathbf{185.82 \pm 7.04}$
Field 2	S_6	141.60 ± 7.07
	S_7	101.57 ± 5.07
	S_8	108.67 ± 5.43
	S_9	137.79 ± 6.88
	S_{10}	106.33 ± 5.31
	Average	$\mathbf{119.19 \pm 5.95}$
Field 3	S_{11}	182.32 ± 9.11
	S_{12}	123.23 ± 6.16
	S_{13}	106.16 ± 5.30
	S_{14}	127.01 ± 6.35
	S_{15}	305.78 ± 15.28
	Average	$\mathbf{168.90 \pm 8.44}$
Field 4	S_{16}	248.82 ± 12.44
	S_{17}	168.80 ± 8.43
	Average	$208.81 \pm \mathbf{10.44}$

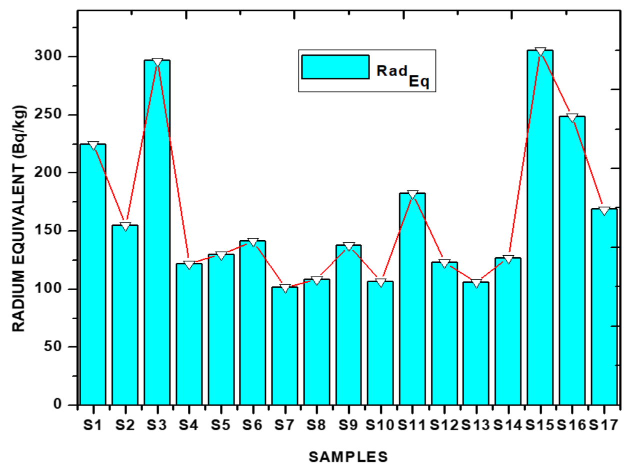

Fig. 2. Graphical representations of Ra_{eq} against samples in this study

The average external hazard indices for the fields were 0.59 ± 0.02 mSv/y, 0.37 ± 0.01 mSv/y, 0.54 ± 0.02 mSv/y and 0.65 ± 0.03 mSv/y for fields 1, 2, 3 and 4 respectively. All the average external hazard indices for the fields were below the world permissible value of 1mSv/y. The graphical representation of the H_{ex} values against the various samples is shown in figure 2.

D. Estimation of Internal Hazard Indices (H_{in})

The internal hazard index is due to inhalation of radon gas and their short-lived decay products. Internal hazard indices were calculated using equation 3 [16],

$$H_{in} = \frac{A_u}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (3)$$

Where A_u, A_{Th} and A_k are activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bqkg^{-1} respectively.

Both the External and Internal hazard indices were tabulated as shown in table 2.

Table 2
Internal hazard index (H_{in}) and External hazard index (H_{ex}) of the samples collected and measured in this study

	Sample	H_{in} (mSv/y)	H_{ex} (mSv/y)
Field 1	S_1	0.61 ± 0.00	0.66 ± 0.03
	S_2	0.42 ± 0.02	0.49 ± 0.02
	S_3	0.80 ± 0.04	0.92 ± 0.04
	S_4	0.33 ± 0.01	0.42 ± 0.02
	S_5	0.35 ± 0.01	0.45 ± 0.02
	Average hazard index	$\mathbf{0.50 \pm 0.02}$	$\mathbf{0.59 \pm 0.02}$
Field 2	S_6	0.38 ± 0.01	0.48 ± 0.02
	S_7	0.28 ± 0.01	0.33 ± 0.01
	S_8	0.29 ± 0.01	0.32 ± 0.01
	S_9	0.37 ± 0.01	0.39 ± 0.01
	S_{10}	0.29 ± 0.01	0.32 ± 0.01
	Average hazard index	$\mathbf{0.32 \pm 0.01}$	$\mathbf{0.37 \pm 0.01}$
Field 3	S_{11}	0.49 ± 0.02	0.62 ± 0.03
	S_{12}	0.33 ± 0.01	0.38 ± 0.01
	S_{13}	0.28 ± 0.01	0.34 ± 0.01
	S_{14}	0.34 ± 0.02	0.41 ± 0.02
	S_{15}	0.83 ± 0.04	0.94 ± 0.04
	Average hazard index	$\mathbf{0.45 \pm 0.02}$	$\mathbf{0.54 \pm 0.02}$
Field 4	S_{16}	0.67 ± 0.03	0.78 ± 0.03
	S_{17}	0.46 ± 0.02	0.51 ± 0.02
	Average hazard index	$\mathbf{0.57 \pm 0.03}$	$\mathbf{0.65 \pm 0.03}$

The average internal hazard index was 0.50 ± 0.02 mSv/y, 0.32 ± 0.01 mSv/y, 0.45 ± 0.03 mSv/y and 0.57 ± 0.03 mSv/y for fields 1, 2, 3 and 4 respectively. It can be noted that H_{ex} and H_{in} values from the various fields were different since the activity concentrations of the samples were also different. However, all the hazard indices H_{in} were below the safety limit of 1mSv/y.

A graphical representation of H_{ex} and H_{in} values of this is shown in figure 3.

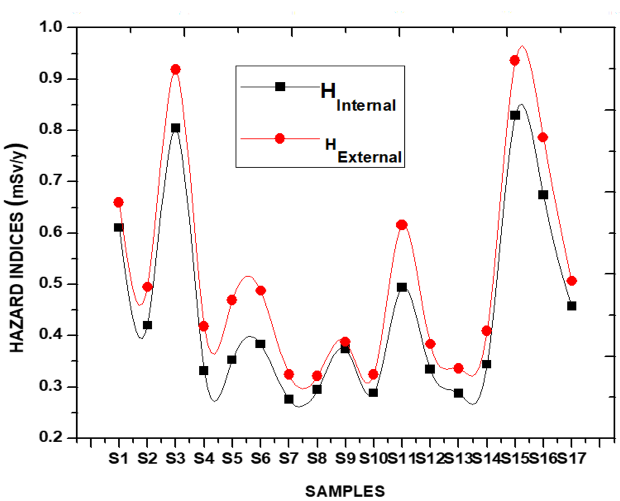

Fig. 3. Representation of internal and external hazard indices in this study

4. Conclusion

An assessment of natural radionuclides of ^{238}U, ^{232}Th and ^{40}K have been measured in the top soils of Ahero fields Kisumu County, Kenya using gamma ray spectroscopy. The average activity concentrations for the three radionuclides in all the four were within the permissible levels. All the values of radium equivalent and the hazard indices from all samples from the four fields were within the acceptable levels of 370 Bq/kg and 1msv/y, thus the exposure risk to the farmers and general population at the study area is insignificant. However, there is need for radiological risk assessment to be carried out on the rice components and other crops grown at the study area to provide comprehensive information on radiation safety.

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References

[1] Tzortzis, M., Svoukis, E., & Tsertos, H. (2004). A comprehensive study of natural gamma radioactivity levels and associated dose rates from surface soils in Cyprus. *Radiation protection dosimetry*, *109*(3), 217-224.

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

[3] 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 to the General Assembly, with Scientific Annexes. United Nations.

[4] Vanmarcke, H. (2002). UNSCEAR 2000: sources of ionizing radiation. *Annalen van de Belgische vereniging voor stralings bescherming*, *27*(2), 41-65.

[5] Gaafar, I., Elbarbary, M., Sayyed, M. I., Sulieman, A., Tamam, N., Khandaker, M. U., ... & Hanfi, M. Y. (2022). Assessment of Radioactive Materials in Albite Granites from Abu Rusheid and Um Naggat, Central Eastern Desert, Egypt. *Minerals*, *12*(2), 120.

[6] Nwaka, B. U., & Jibiri, N. N. (2018). External and internal radiation doses from chemical fertilizers used in Ibadan, Oyo State, Nigeria. *Glob J Sci Front Res Phys Space Sci*, *18*(4), 73-81.

[7] Ugbede, F. O., Osahon, O. D., & Agbalagba, E. O. (2021). Radiological Risk Assessment of 238U, 232Th and 40 K in Soil and Their Uptake by Rice Cultivated in CAS Paddy Environment of Abakaliki, Nigeria. *Chemistry Africa*, 1-11.

[8] Nahar, A., Asaduzzaman, K., Islam, M. M., Rahman, M. M., & Begum, M. (2018). Assessment of natural radioactivity in rice and their associated population dose estimation. *Radiation Effects and Defects in Solids*, *173*(11-12), 1105-1114.

[9] Alrefae, T., & Nageswaran, T. N. (2013). Radioactivity of long-lived gamma emitters in rice consumed in Kuwait. *Journal of the Association of Arab Universities for Basic and Applied Sciences*, *13*(1), 24-27

[10] Njenga, L. W. Department/unit: Department of Chemistry. *Exchange, 70(252,000.00),70-000.*

[11] M'marete, C. K. (1991). The bearing capacity of the soils of Ahero irrigated rice fields under the exposure to land preparation traffic (Doctoral dissertation, University of Nairobi).

[12] Raburu, P. O., Khisa, P., & Masese, F. O. (2012). Background information on Nyando Wetland.

[13] Mukanda, K. W., Waswa, M. N., & Ouma, L. (2022). Radiological risk assessment of 238U, 232TH and 40K in the top soils of ahero paddy fields of Kisumu County, Kenya. *ITEGAM-JETIA*, *8*(36), 32-36.

[14] Dizman, S., Görür, F. K., Keser, R., & Görür, O. (2019). The assessment of radioactivity and radiological hazards in soils of Bolu province, Turkey. *Environmental Forensics*, *20*(3), 211-218.

[15] 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 to the General Assembly, with Scientific Annexes. United Nations.

[16] Gad, A., Saleh, A., & Khalifa, M. (2019). Assessment of natural radionuclides and related occupational risk in agricultural soil, southeastern Nile Delta, Egypt. *Arabian Journal of Geosciences*, *12*(6), 1-15.