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RESEARCH ARTICLE OPEN ACCESS

MONITORING OF ANNUAL EFFECTIVE DOSE (AED) IN SURFACE SOILS OF AHERO RICE FIELDS, KENYA

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ABSTRACT

The annual effective doses (AED) both AED (in) and AED (out) in the surface soils of Ahero rice fields, Kenya were investigated. The associated health risk of the soils from the four fields Field 1, Field 2, Field 3 and Field 4 was measured using gamma ray spectrometric technique employing Sodium Iodide Thallium doped detector. Five surface soil samples were collected at a depth of 15 – 20 cm from the Field 1, Field 2, Field 3 and two samples from Field 4. The average AED (in) of 0.30 ± 0.01 mSv/y and an average AED (out) of 0.20 ± 0.01 mSv/y for field 1, an average AED (in) of 0.19 ± 0.01 mSv/y, an average AED (out) of 0.20 ± 0.01 mSv/y for field 2, an average AED (in) of 0.28 ± 0.01 mSv/y and an average AED (out) of 0.18 ± 0.01 mSv/y for field 3 and an average AED (in) of 0.34 ± 0.01 mSv/y and an average AED (out) of 0.23 ± 0.01 mSv/y for field 4. All the AED values both in and out from the four fields were below the recommended level of 1mSv/y. The values indicate that there is no health hazard associated with the surface soils of the study area to the farmers and the general population.

I. INTRODUCTION

The concentration of natural radionuclides of ^{238}U, ^{232}Th and singly occurring ^{40}K in the soils have a direct bearing on the terrestrial radiatiation [1]. The three radionuclides are found in significant concentrations in the soils [2]. It is worth noting that natural radioactivity depends on the geological formations of the place [3]. Anthropogenic activities especially Agricultural based ones in an attempt to replenish the soils with nutrients using inorganic fertilizers adds to the radioactivity levels to the soils [4]. The hazards of exposure due to the radionuclides has formed a basis of major concern in the recent times [5]. The associated effects of exposure to the varying levels of radiations from ^{238}U, ^{232}Th and ^{40}K have been broadly discussed in various literature [6]. The Ahero rice fields are part of the larger Nyando wetlands region. This region is characterized by a Precambrian system of granodiorites that are granitic in nature [7]. The granitic rocks have higher concentrations of ^{238}U [8]. It is estimated that every year there are 40000 new cancer cases and over 27000 deaths in Kenya [9]. ^{238}U and ^{232}Th are highly radiotoxic. Individuals exposed to high amounts of ^{232}Th have an increased risk of bone cancer while ingestion of large concentrations of ^{238}U can cause lung cancer and kidney damage [10]. ^{40}K on the other hand is a mineral required by the human body muscles to work efficiently. It helps in the functioning of the nerves and muscle contraction. However, too much of ^{40}K in the body can affect the working of the muscles of the heart; an irregular heart beat which may result in to heart attack and in worst cases death.

The farmers and the general public are in direct contact with the soil, fertilizers and untreated water from river Nyando [11]. They inhale the dust particles of the soils which find their way in to the body through the respiratory system [12]. The radionuclides of ^{238}U, ^{232}Th and ^{40}K have very long half-lives [1]. Farming in Ahero fields is not void of use of inorganic fertilizers especially phosphatic ones. These phosphatic fertilizers originate from rocks that are highly rich in ^{238}U [13]. The addition and hence accumulation of natural radionuclides in the top soils is potentially hazardous to the human health and environment [12]. According to a study by [14], there were cases of reported skin burns when the study was conducted at four health care providers. The skin burns can be attributed to the direct irradiation from the radionuclides.

This study of monitoring annual effective doses (AED) both AED (in) and AED (out) in the surface soils of Ahero rice fields was therefore undertaken to assess the radiological risk associated with the interaction of the soils by the farmers and the general public since no similar study had been done at the study area.

II. MATERIALS AND METHODS

II.1 STUDY AREA

The present study was conducted at the Ahero rice fields (Ahero Irrigation Scheme - AIS). The study area is located on latitude on latitude 00˚9˝S and longitude 34˚56˝E and at an altitude of 1160m above sea level [7]. Ahero fields is found in Muhoroni Sub County that has a population of 151799 [15]. These fields are characterized by vertisols just like other National Irrigation Schemes [16]. The soils are suitable for irrigation of rice due to their low percolation rates. The source of water for irrigation in the Ahero fields is river Nyando whose river bed is also characterized by rocks of granitic nature [7]. Map showing Ahero Irrigation Scheme where the study was done is as shown in figure 1 below.

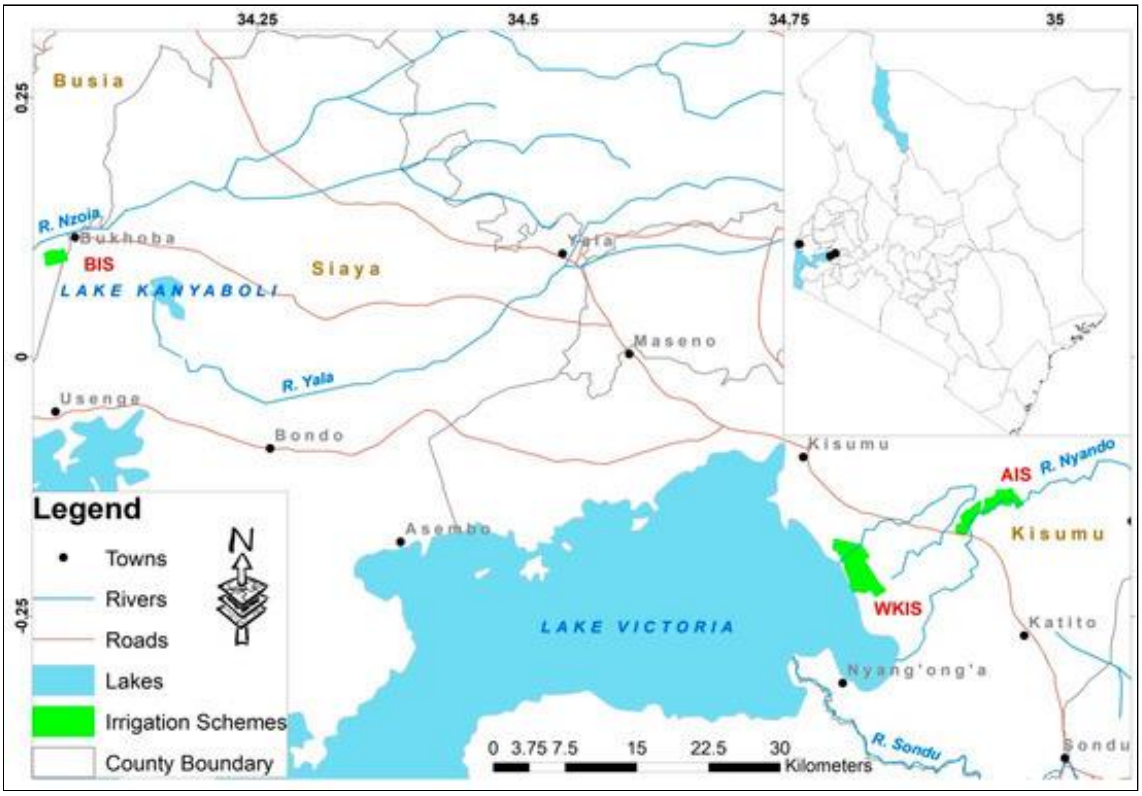

Figure 1: Map of Ahero irrigation scheme (google map).
Source: Authors, (2023).

II.2 SAMPLE COLLECTION AND PREPARATION

A total of 17 surface samples at the depths of 15 – 20 cm were collected. Samples S_1 to S_5 were from a field where rice was already transplanted (field 1), S_6 to S_{10} samples were collected from a field where transplanting was being done (field 2), S_{11} to S_{15} samples were collected from a field where rice had already been harvested and cultivation done (field 3), S_{16} and S_{17} samples were collected from a field that had not been cultivated for 2 years. The samples were properly labelled and spread on mats in the laboratory to dry for two weeks (14 days) to dry. They were then crushed using mortar and pestle then sieved through a 2.00 mm sieve (< 2.00 mm particles were used).

170 g of each sample from the fields was weighed in to cylindrical plastic containers of uniform geometry. The containers were properly labeled and hermetically sealed. The samples were then kept for 30 days to allow for ^{232}Th and ^{238}U and their short lived progenies to reach secular equilibrium before counting [17, 18].

II.3 GAMMA RAY SPECTROSCOPIC ANALYSIS

NaI (Ti) gamma ray spectrometer was used in the spectral acquisition and analysis [11]. The spectrometry system consisted of 76 mm by 76 mm single crystal of Thallium activated Sodium Iodide. Spectrum acquisition and processing was made possible by coupling the detector output to a multichannel Analyzer (MCA). The energy calibration of the detector was done using the energy peaks of The energy calibration of the gamma ray spectrometer was done using the energy peaks of 662 KeV of ^{137}Cs**,** 1170 KeV and 1330 KeV of ^{60}Co [19]. The masses used were 1.2g for ^{137}Cs and 6.7g for ^{60}Co.

Gamma rays from the soil sample strikes the NaI (Ti) crystal emitting photons that dislodge electrons from the photocathode. The photoelectrons produced are collected by the pre – amplifier and shaped into voltage pulses. The pulses are multiplied in the photomultiplier by a series of dynodes. Finally, the MCA digitizes the pulses and the output is displayed through personal computer

III. RADIATION LEVEL MEASUREMENTS

III.1 ABSORBED DOSE RATE (ADR)

The ADR values shown in table 1 below used in the determination of AED were got from the study by [11] at the same study area.

Table 1: Absorbed Dose Rate of samples collected.

	Sample	Absorbed Dose Rate (nGy/h)
Field 1	S_1	98.35 ± 4.91
	S_2	67.73 ± 3.38
	S_3	130.84 ± 6.54
	S_4	53.40 ± 2.67
	S_5	57.18 ± 2.85
	Average ADR	$\mathbf{81.50 \pm 4.07}$
Field 2	S_6	62.68 ± 3.12
	S_7	44.55 ± 2.22
	S_8	47.81 ± 2.39
	S_9	61.12 ± 3.05
	S_{10}	$46.97.18 \pm 2.34$
	Average ADR	$\mathbf{52.59 \pm 2.62}$
Field 3	S_{11}	80.78 ± 4.03
	S_{12}	53.97 ± 2.69
	S_{13}	47.14 ± 2.35
	S_{14}	56.23 ± 2.81
	S_{15}	135.28 ± 6.76
	Average ADR	$\mathbf{74.68 \pm 3.73}$
Field 4	S_{16}	109.47 ± 5.47
	S_{17}	74.10 ± 3.70
	Average ADR	$\mathbf{91.79 \pm 4.59}$

Source: [11].

III.2 ANNUAL EFFECTIVE DOSE (AED)

In determining the outdoor AED to the population, the occupancy factor was put into consideration [20]. The annual effective dose AED(in) and AED (out) were determined using equations 1 and 2 respectively [21].

$$AED\,(\text{in}) = ADR \times 8760 \times 0.8 \times 0.7 \times 10^{-6} \qquad (1)$$

$$AED\,(\text{out}) = ADR \times 8760 \times 0.4 \times 0.7 \times 10^{-6} \qquad (2)$$

Where $AED\,(\text{in})$ and $AED\,(\text{out})$ are Annual Effective Doses for indoor and outdoor environments respectively, ADR is the absorbed dose rate in air in nGy/h, 0.7 (SvGy) is the conversion factor for absorbed dose rate in air to an effective dose, 0.8 is the indoor occupancy factor while 0.4 is the outdoor occupancy factor. The units of AED are milliSierverts per year (mSv/y).

IV. RESULTS AND DISCUSSIONS

IV.1 DETERMINATION OF ANNUAL EFFECTIVE DOSE

The AED (in) and AED (out) were determined and the results tabulated in table 2. The results were also represented in figure 2.

Table 2: A summary of indoor and Outdoor Annual Effective Dose Rates for all the samples in this study.

	Sample	AED (in) mSv/y	AED (out) mSv/y
Field 1	S_1	0.36 ± 0.01	0.24 ± 0.01
	S_2	0.25 ± 0.01	0.17 ± 0.01
	S_3	0.48 ± 0.01	0.32 ± 0.01
	S_4	0.20 ± 0.01	0.13 ± 0.01
	S_5	0.21 ± 0.01	0.14 ± 0.01
	Average AED	$\mathbf{0.30 \pm 0.01}$	$\mathbf{0.20 \pm 0.01}$
Field 2	S_6	0.23 ± 0.01	0.15 ± 0.01
	S_7	0.16 ± 0.01	0.11 ± 0.01
	S_8	0.18 ± 0.01	0.12 ± 0.01
	S_9	0.22 ± 0.01	0.15 ± 0.01
	S_{10}	0.17 ± 0.01	0.12 ± 0.01
	Average AED	$\mathbf{0.19 \pm 0.01}$	$\mathbf{0.13 \pm 0.01}$
Field 3	S_{11}	0.30 ± 0.01	0.20 ± 0.01
	S_{12}	0.20 ± 0.01	0.13 ± 0.01
	S_{13}	0.17 ± 0.01	0.12 ± 0.01
	S_{14}	0.21 ± 0.01	0.14 ± 0.01
	S_{15}	0.50 ± 0.01	0.33 ± 0.01
	Average AED	$\mathbf{0.28 \pm 0.01}$	$\mathbf{0.18 \pm 0.01}$
Field 4	S_{16}	0.40 ± 0.01	0.27 ± 0.01
	S_{17}	0.27 ± 0.01	0.18 ± 0.01
	Average AED	$\mathbf{0.34 \pm 0.02}$	$\mathbf{0.23 \pm 0.01}$

Source: Authors, (2023).

From the Table 2, soil samples from field 1 had an average AED (in) of 0.30 ± 0.01 mSv/y and an average AED (out) of 0.20 ± 0.01 mSv/y, an average AED (in) of 0.19 ± 0.01 mSv/y, an average AED (out) of 0.20 ± 0.01 mSv/y for field 2, an average AED (in) of 0.28 ± 0.01 mSv/y and an average AED (out) of 0.18 ± 0.01 mSv/y for field 3 and an average AED (in) of 0.34 ± 0.01 mSv/y and an average AED (out) of 0.23 ± 0.01 mSv/y for field 4. The average AED (in) and average AED (out) for field 4 were higher, this is because although the field had not been used for 2 years, accumulation of the radionuclides had taken place due to continuous use of inorganic fertilizers.

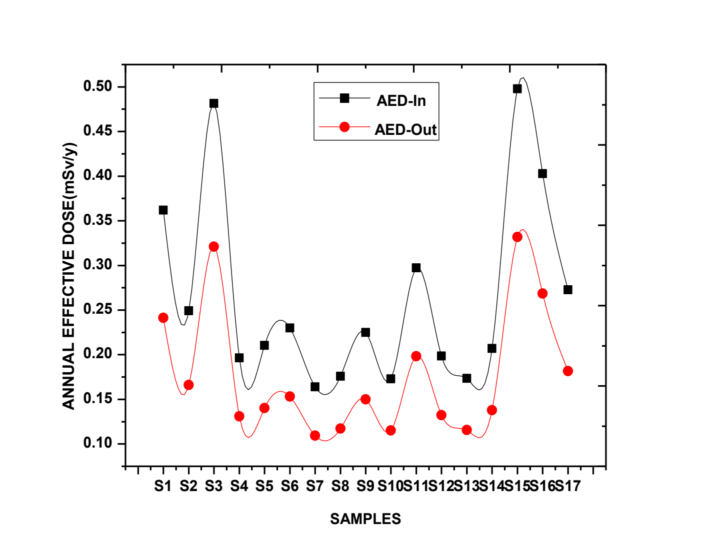

Figure 2: Indoor and Outdoor Annual Effective Doses for the collected samples.
Source: Authors, (2023).

It can be noticed from the results that all the fields had their AED (in) and AED (out) above the world value of 0.07 mSv/y [2]. Although all samples had high AED (in) and AED (out) than the world levels, their values were below the world permissible value of 1 mSv/y.

V. CONCLUSIONS

An investiagation of annual effective dose in the surface soils of Ahero rice fields, Kenya has been done using gamma ray spectroscopy. The average AED (in) and AED (out) values from all the four fields were below the permissible level of 1mSv/y [22]. Thus the interaction of the population with the soils does not pose a health hazard. However, a study needs to be done to assess the AED (in) and AED (out) in the rice components and other crops cultivated at the study area for example Soy beans, maize and water melons to provide a comprehensive data base information on radiation safety.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.
Methodology: Mukanda Kere Wanyama and Michael Nakitare Waswa.
Investigation: Mukanda Kere Wanyama and Michael Nakitare Waswa.
Discussion of results: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.
Writing – Original Draft: Mukanda Kere Wanyama.
Writing – Review and Editing: Mukanda Kere Wanyama and Michael Nakitare Waswa.
Resources: Linda Ouma.
Supervision: Michael Nakitare Waswa and Linda Ouma.
Approval of the final text: Mukanda Kere Wanyama, Michael Nakitare Waswa and Linda Ouma.

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