



## Determination of Radiobiological impact parameters in soil from Sugarcane Farmland Cultivated with Waste Water in Jibiya, Katsina State-Nigeria

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### ABSTRACT

*This study was conducted to investigate the radiological impact parameters in soil samples collected from a sugarcane farmland cultivated with waste water in Jibiya, Katsina State- Nigeria using  $\gamma$ -ray spectrometry technique with sodium iodide (NaI(Tl)) low level background detector. In the results, the average specific activities of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were found to be  $(18.12 \pm 0.43) \text{ BqKg}^{-1}$ ,  $(29.189 \pm 0.78) \text{ BqKg}^{-1}$  and  $(67.432 \pm 1.024) \text{ BqKg}^{-1}$  respectively; And are all within the world average values of  $33 \text{ BqKg}^{-1}$ ,  $45 \text{ BqKg}^{-1}$  and  $420 \text{ BqKg}^{-1}$ . Similarly, the health effects of natural radioactivity in the soil samples caused by these primordial radionuclides was computed using the absorbed dose (D), Annual effective dose equivalent (AEDE), Radium equivalent activity ( $Ra_{eq}$ ), External hazard index ( $H_{ext.}$ ), Gamma representative level index ( $I_\gamma$ ) and excess life cancer risk (ECLR) and were all within the world recommended average values; Except ECLR that is above world average value as recommended by UNSCEAR, 2000, implying potential cancer risk to the farmers in the study area. Although this study shows that radioactivity level is normal in the study areas, periodic evaluation of the radioactivity level is recommended.*

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### INTRODUCTION

Assessment of primordial radionuclides ( $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ ) in soil used for building construction as well as for agricultural purpose in any region is of great importance due to role the soil plays in these key sectors. And the amount of terrestrial gamma radiation (TGR) received by human body depend mainly on the concentration of these primordial radionuclides and varies depending on some factors such as soil type, geological formation, geographical location, time and also some human activities in that particular region (UNSCEAR,2000). The effect of radiation exposure caused to human health by

health by primordial radionuclides account to about 80% of the total external radiation exposure to the body considering their gamma ray emitting potentials (Olagbaju *et al.*, 2021 and Kolo *et al.*, 2017). And External exposure of the public due to TGR is the second largest contributor with 0.48 mSv (20%) of the total annual dose of 2.4 mSv per inhabitant (Emmanuel *et al.*, 2018 and Al-Khawlanly *et al.*, 2019). Basically, the ideal ecosystem is considered to be in radiological equilibrium in any naturally and undisturbed environmental medium as far as primordial radionuclides and their decay

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But rapid exploitation of natural resources, technological advancement, industrial and agricultural expansions, etc., have altered its natural state; causing unforeseen consequences for life and health; now and in the future (kolo et al., 2017 and Michalik, et al.,2013). Several authors have reported on radiological impact of primordial radionuclides on both soil and food grown on them to ensure food safety and healthy environment. Nigeria for instance, terrestrial gamma radiation (TGR) assessment using different techniques

**Materials and Methods**  
**Description of the study area**

The study area is located behind Jibiya water treatment plant. Jibiya lie between Latitude 13° 05' 30" N and Longitude 07° 13' 35" E in Jibiya, Katsina state Nigeria; has total annual rainfall around 600-700mm, characterized by high temperature of about 40°C, constant low relative humidity 50%, shorter raining

has received great national interest in various parts of the country (Abba et al., 2017). This present study is focused on the determination of radiological impact assessment of soil from sugarcane farmland that is cultivated with wastewater in Jibiya, Katsina State-Nigeria with a view to ascertain whether the effluent water from a treatment plant can result to potential threads in soil, sugarcane and also the farmers directly using it for their irrigation farming in the area.

season with light and sandy loamy soils that is alkaline (pH 7.2 – 9.8). The major occupation of the people in this area is agriculture which provide job to about 85% of the total population in various agricultural practices such as farming, livestock rearing and poultry etc, while the remaining 15% are engaged in other occupations such as trading, carpentry and blacksmithing etc. The area is dominated mainly by Hausa and Fulani (El-Ladan and Maiwada, 2014; Suleiman and Audu, 2013; Katsina, 2003).

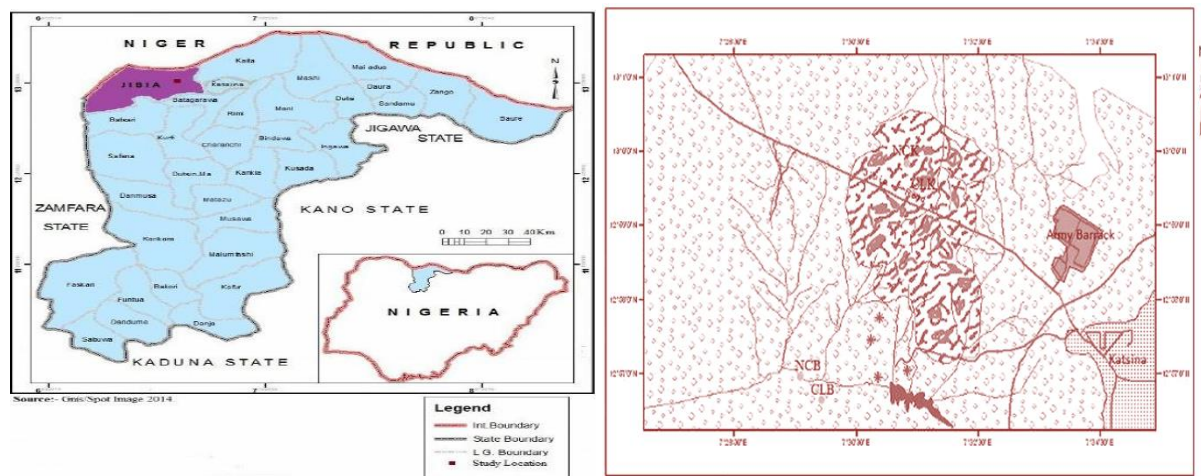


Figure 1: Map showing the sampling sites, adapted from Google earth 2009 imaginary.

**Sample Collection and Preparation**

A total of twenty-seven samples from surface soil were collected randomly at different points within the study area at 0-10cm depth. All the samples were

dried in an oven at 105°C for 24 hours, crushed and sieved using a 2mm mesh. 500g of each prepared sample was then transferred into clean empty plastic containers with dimensions 7 cm in diameter and

10 cm in height and well labeled. The containers were then sealed tightly with the gap between the cap and container wrapped with thick vinyl tape and the stored for a period of about 4 weeks to enable  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$  reach their secular equilibrium with its decay products in the Uranium and Thorium series, respectively (Ferdous, *et al.*, 2015). The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain data on  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$ . The spectrometer used was a CANBERRA France lead shielded 7.6cm x 7.6cm low background NaI(Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base. The system was calibrated using standard point sources of gamma emitting isotopes. The resolution of the detector is about 10% at 0.662MeV of  $^{137}\text{Cs}$ . Each prepared sample was counted for a period of 3 hours and activity concentrations of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were determined using the gamma-lines of their decay products with the photo peak regions of  $^{40}\text{K}$  (1.46 MeV),  $^{214}\text{Bi}$  (1.76 MeV) and  $^{208}\text{Tl}$  (2.615 MeV) respectively (Olagbaju *et al.*, 2021).

#### Activity concentration and Radiological hazard assessments

The activity concentration  $A(\text{Bq/kg})$  of the radionuclides were calculated using equation (1).

$$A(\text{Bq/kg}) = \tau C_{\eta} \quad (1)$$

Where  $\tau = \frac{1}{\epsilon \rho_{\gamma} \omega}$ ,  $\rho_{\gamma}$  = absolute transition probability of the specific gamma-ray

$\omega$  = sample weight,  $\epsilon$  = efficiency of the detector for a particular gamma-ray energy emitted

$C_{\eta}$  = Efficiency of the detector for a particular gamma-ray energy emitted.

The risk assessment of radionuclides in human was assessed through various estimating parameters as well as simulation models that follows:

**Radium equivalent activity ( $R_{\text{eq}}$ ):**- Represent the weighted sum of activity level of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  which takes into account the radiological hazards associated with them and has been calculated on the estimation that 370  $\text{Bqkg}^{-1}$  of  $^{226}\text{Ra}$ , 259  $\text{Bqkg}^{-1}$  of  $^{232}\text{Th}$  and 4810  $\text{Bqkg}^{-1}$  of  $^{40}\text{K}$  produce the same gamma radiation dose rate (uosif *et al.*, 2014; Mohanty *et al.*, 2004).

$$R_{\text{eq}}(\text{Bqkg}^{-1}) = A_{\text{Ra}} + 1.43A_{\text{Th}} + 0.077A_{\text{K}} \quad (2)$$

Where:  $A_{\text{Ra}}$ ,  $A_{\text{Th}}$  and  $A_{\text{K}}$  are the activities concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in  $\text{Bqkg}^{-1}$  respectively. And  $^{226}\text{Ra}$  represent maximum value of  $A_{\text{U}}$  in this study.

**Absorbed gamma dose rate ( $D_{\gamma}$ )** This refers to the dose received in air at 1m above the ground surface for uniform distribution of the naturally occurring radionuclides ( $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ ); and was calculated using equation (2) according to (uosif *et al.*, 2014, Ross and Raiz, 2008).

$$D_{\gamma}(\text{nGyh}^{-1}) = 0.462A_{\text{U}} + 0.604A_{\text{Th}} + 0.0417A_{\text{K}} \quad (3)$$

Where:  $A_{\text{U}}$ ,  $A_{\text{Th}}$ , and  $A_{\text{K}}$  retain their usual meanings as in equation (2).

**Annual effective dose equivalent (AEDE)** AEDE Refers to the exposure risk to any individual due to absorbed dose rate by applying a conversion factor of  $0.7\text{SvGy}^{-1}$ , outdoor occupancy factor of 0.2, and indoor occupancy factor of 0.8 proposed by UNSCEAR report (UNSCEAR, 2000, UNSCEAR, 2008). Hence the AEDE was calculated using equation (4) (Joseph *et al.*, 2022).

$$AEDE_{out}(mSv.y^{-1}) = D_y(nGy/h) \times 10^{-6} \times 8760hy^{-1} \times 0.2 \times 0.7(SvGy^{-1}) \quad (4)$$

Where: 8760 is the time in hour for one year,  $10^{-6}$  is the conversion factor from *nano* to *milli*.

**Gamma/external index ( $I_\gamma$ ):** is a screening index used for selecting and categorizing building materials in order to minimize excess gamma radiation to which occupants of a building are exposed to. It was calculated using equation 6. (Ekpe *et al.*, 2022)

$$I_\gamma(BqKg^{-1}) = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (5)$$

Where:  $A_U$ ,  $A_{Th}$ , and  $A_K$  retain their usual meanings as in equation (2). For  $I_\gamma \leq 1$ , corresponds to dose rate of  $0.3mSvy^{-1}$ ,  $I_\gamma \leq 3$ , corresponds to dose rate of  $1mSvy^{-1}$ ; And building materials with  $I_\gamma > 3$  are prohibited for use as building materials.

## Results and discussions

Table 1 present the measured activity concentration as well as the calculated radiological hazard indices in the study area. From the table, the Minimum, Maximum and Mean $\pm$ S.E of  $^{238}U$ ,  $^{232}Th$  and  $^{40}K$  were found to be (14.7, 21.7 and  $18.12\pm 0.43$ ) ( $Bqkg^{-1}$ ) for  $^{238}U$ ; (22.74, 36.45 and  $29.19\pm 0.78$ ) ( $Bqkg^{-1}$ ) for  $^{232}Th$ ; (58.65, 78.65 and  $67.43\pm 1.02$ ) ( $Bqkg^{-1}$ ) for  $^{40}K$  respectively. It was observed from the table that the average measured activity of these radionuclides was below the world average value in comparison as reported by UNSCEAR,2000. This may be due to geological composition of the area which is mainly sedimentary rock in nature. Figure 1.1 shows the percentage distribution of the measured activity concentration. From the figure, out of total measured concentrations of 114.73Bq/kg, 15.8% represent  $^{238}U$ , 25.43% represent  $^{232}Th$  and the remaining 58.77% is for  $^{40}K$ .

This implies that  $^{40}K$  contribute more to terrestrial radiation in the study area, followed by  $^{232}Th$  and least  $^{238}U$ . Furthermore, the highest measured concentration for  $^{238}U$ ,  $^{232}Th$  and  $^{40}K$  were observed at sampling points 24, 26 and 19 respectively. The highest recorded values at these sampling points may be due anthropogenic influences of chemical and other reagents in water treatment plant taking place in those areas. Also, from the table 1, the radiobiological indices such as dose rate, Annual effective dose equivalent, Radium equivalent, External hazard index, gamma representative index as well as Excess lifetime cancer risk were calculated and presented in figure 1.2. their average values are:  $28.82\pm 0.482$  nGy/h,  $0.035\pm 0.0006$  mSv/y,  $65.057\pm 1.133$  Bq/kg,  $0.176\pm 0.0031$  Bq/kg,  $0.229\pm 0.003$  Bq/kg and  $0.124\pm 0.002$  respectively. The radiobiological indices calculated above were all within UNSCEAR, 2000 and ICRP 1999 reports, except the excess lifetime cancer risk (ELCR) that were above the recommended world average limit as reported by UNSCEAR, 2000. The average ELCR of  $0.124\pm 0.002$  obtained in the present study implies that one in every ten farmers that are working directly in that farmland are at a risk of suffering from cancer in their lifetime when exposed to average annual effective dose rate (AEDE) of  $0.035 mSv.y^{-1}$  at 70years and above, from ionizing radiation been emitted by radionuclides in the soil from study area; as against three per thousand inhabitants as proposed by UNSCEAR (2000).

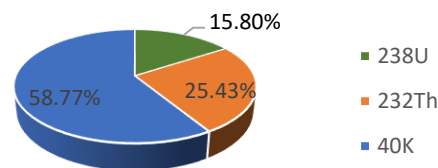


Figure 1.1: Percentage distribution of measured radionuclide

Table 1: Activity concentration and radiological parameters

	U(Bq/Kg)	Th(Bq/Kg)	K(Bq/Kg)	Dose rat	AEDE	Raeq.	Hext	Iy	ELCR
	16.056	22.736	73.53	24.19075	0.029668	54.17429	0.146314	0.191523	0.103836
	15.935	29.638	66.05	28.01761	0.034361	63.40319	0.171232	0.223323	0.120263
	19.76	23.548	69.26	26.24025	0.032181	58.76666	0.158723	0.206693	0.112634
	18.935	24.766	58.65	26.15234	0.032073	58.86643	0.158991	0.206497	0.112256
	14.7	30.45	66.1	27.93957	0.034265	63.3332	0.17104	0.223283	0.119928
	20.76	32.736	58.65	31.80937	0.039011	72.08853	0.194695	0.25243	0.136539
	19.115	29.766	69.18	29.6946	0.036417	67.00724	0.180971	0.235607	0.127461
	14.82	28.142	58.65	26.29031	0.032242	59.57911	0.160904	0.20966	0.112849
	16.055	27.33	70.4	26.86041	0.032942	60.5577	0.163549	0.213633	0.115296
	18.7	28.548	68.04	28.71966	0.035222	64.76272	0.17491	0.227753	0.123276
	19.88	31.112	61.78	30.55243	0.03747	69.12722	0.186697	0.24242	0.131143
	15.935	23.548	67.88	24.41556	0.029943	54.8354	0.148099	0.193483	0.104801
	19.995	24.766	59.26	26.6675	0.032705	59.9734	0.161982	0.210233	0.114468
	15.935	36.39	63.71	31.99824	0.039243	72.87837	0.196815	0.256303	0.137349
	18.525	31.112	74.91	30.47395	0.037373	68.78323	0.185765	0.24228	0.130806
	21.465	24.36	71.26	27.60181	0.033851	61.78682	0.166883	0.217103	0.118478
	17.29	34.706	73.4	32.01118	0.039259	72.57138	0.19599	0.25563	0.137405
	17.88	30.706	63.61	29.45952	0.036129	66.68755	0.180105	0.234333	0.126452
	16.055	23.142	78.65	24.67488	0.030261	55.20411	0.149095	0.195443	0.105914
	15.935	33.548	71.3	30.59817	0.037526	69.39874	0.18742	0.244623	0.13134
	20.995	30.112	62.92	30.5111	0.037419	68.9	0.186087	0.241517	0.130966
	21.465	24.36	74.91	27.75402	0.034038	62.06787	0.167641	0.21832	0.119131
	18.645	29.518	68.04	29.28013	0.035909	66.09482	0.178507	0.23242	0.125682
	21.7	33.548	65.52	33.02058	0.040496	74.71868	0.201799	0.261913	0.141738
	16.23	31.548	70.85	29.5077	0.036188	66.79909	0.180402	0.235457	0.126659
	15.935	36.45	64.91	32.08452	0.039348	73.05657	0.197296	0.257003	0.13772
	20.7	31.518	69.26	31.48841	0.038617	71.10376	0.192036	0.249677	0.135161
Minimum	14.7	22.736	58.65	24.19075	0.029668	54.17429	0.146314	0.191523	0.103836
Maximum	21.7	36.45	78.65	33.02058	0.040496	74.71868	0.201799	0.261913	0.141738
Mean	18.12389	29.18904	67.43259	28.81535	0.035339	65.05652	0.175702	0.228836	0.123687
S. E	0.426518	0.77861	1.02365	0.481431	0.00059	1.13253	0.003058	0.00393	0.002066
<b>World Average</b>	<b>33</b>	<b>45</b>	<b>420</b>	<b>59</b>	<b>0.07</b>	<b>370</b>	<b>1</b>	<b>1</b>	<b>0.0029</b>

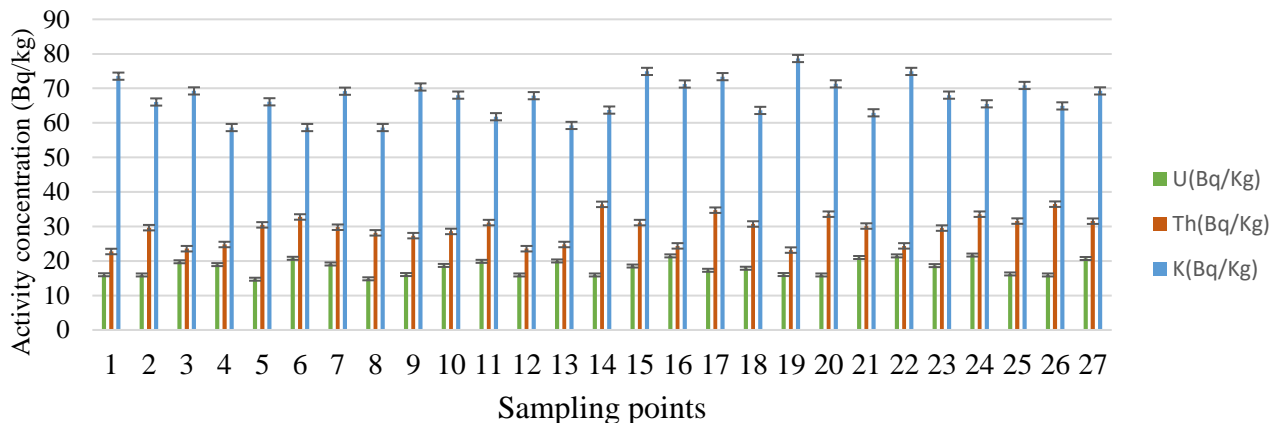


Figure 1.2: Activity concentration of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in (B/kg)

Table 2: Pearson's Correlation matrix for hazard parameters.

	$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$	$D_R$	AEDE	$Ra_{eq}$	$H_{ext}$	$I_y$	ELCR
$^{238}\text{U}$	1.0000								
$^{232}\text{Th}$	-0.1046	1.0000							
$^{40}\text{K}$	-0.1144	-0.2175	1.0000						
$D_R$	0.2970	0.9147	-0.1706	1.0000					
AEDE	0.2970	0.9147	-0.1706	1.0000	1.0000				
$Ra_{eq}$	0.2658	0.9286	-0.1873	0.9993	0.9993	1.0000			
$H_{ext}$	0.2662	0.9285	-0.1873	0.9993	0.9993	1.0000	1.0000		
$I_y$	0.2482	0.9338	-0.1700	0.9987	0.9987	0.9997	0.9997	1.0000	
ELCR	0.2970	0.9147	-0.1706	1.0000	1.0000	0.9993	0.9993	0.9987	1.0000

Table 2 shows the Pearson's correlation coefficient values that describes mutual relationship existing between the calculated radiological parameters. From the matrix table, there exist a little negative correlation between  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  radionuclides ( $r_2 = -0.1046$ ,  $r_2 = -0.1144$  and  $r_2 = -0.2175$ ) for Uranium and Thorium, Uranium and Potassium as well as for Thorium and Potassium respectively. This may imply that the contaminants to the soil caused by these primordial radionuclides are most likely to originated from different sources; And not all are from

the effluent water. Even though the correlation coefficients lie in the same range of description ( $-0.1 < -0.3$ ) with little negative correlation as explained above,  $^{238}\text{U}$  and  $^{232}\text{Th}$  with  $^{238}\text{U}$  and  $^{40}\text{K}$  contaminants to the soil could be traced to the same source which could be from the anthropogenic event (effluent); while the remaining  $^{232}\text{Th}$  and  $^{40}\text{K}$  with a higher correlation coefficient may be due to large natural abundance of  $^{40}\text{K}$  on the earth crust.

Finally, other calculated radiobiological parameters in the table 2 appeared to have very high positive correlation with one another. This implies their contribution to the soil contaminants are mutually dependent on each other.

### Conclusion

Lower activity concentrations of primordial radionuclides compared to UNSCEAR, 2000 were measured, while radiobiological parameters were determined and

found to be within world average value except ELCR; implying potential cancer risk to the farmers within the study area. Furthermore, the results obtained revealed little negative correlation exist between the radionuclides; which implies that their contribution to the soil contaminant originates from different sources. While all the calculated radiobiological parameters recorded a very high positive correlation with each other; implying their contribution to the soil contaminant is a mutually dependent relationship.

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