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Evaluation of Natural Radioactivity Levels in Soil Samples from Eastern and Northern Regions of South Kordofan State, Sudan

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Abstract

The current research is to assess the natural radioactivity level in the soil samples around eastern and northern regions of South Kordofan State. The radioactivity concentration of ^{238}U, ^{232}Th, and ^{40}K have been determined using γ-ray spectroscopy equipped with NaI (Tl) detector, the absorbed dose rate and annual effective dose were assessed. The activity concentration of ^{238}U, ^{232}Th and ^{40}K was 15.44 to 868.24, 7.12 to 406.61 and 226.67 to 2168.52Bqkg^{-1} with average value of 108.82, 98.03 and 1059.13Bqkg^{-1}, respectively. The average values of obtained results were found to be higher than UNSCEAR reported data. The absorbed dose rate and annual effective dose were determined and found to be in range of 23.87 to 586.06nGyh^{-1} and 29.29 to 719.23 μSvy^{-1} with average value of 153.65nGyh^{-1} and 188.56μSvy^{-1}, respectively. The previous analysis has resulted that significant correlation was found between ^{232}Th and both of ^{238}U and ^{40}K (P>0.01), while no correlation was found between ^{238}U and ^{40}K. Estimation of the relative contribution of the ^{238}U, ^{232}Th and ^{40}K to the overall absorbed dose in air discovered that the main contribution comes from ^{232}Th 38.54 %.

Keywords: Natural radioactivity, Soil, South Kordofan State, NaI (Tl) detector.

Introduction

There is a significant interest in the investigation of natural radioactivity in soil due to the people to natural radioactivity at different levels exposure. Natural environmental radioactivity has caused to the performance of comprehensive studies in many states world over[1]. These researches can be profitable for both the estimation of public dose rates and the achievement of epidemiological investigations, as well as to establish main reference for data records, in order to a certain probable changes in the environmental factors. Natural radionuclides have been in existence in the environment since the formation of earth due to the long half-lives of radionuclides such as Uranium and Thorium series and their decay products together with ^{40}K. These radionuclides have different sources, including earth crust, several environmental samples, minerals and air. Investigation and evaluation of natural radioactivity in soil have been conducted indifferent areas of the globe, of ten estimation of the dose and risk resulting[2-7]. Radioactivity radionuclides that represent a potential risk to human health due to the emission of ionizing radiation[8-9]. Environmental radioactivity is widely distributed in the earth's environment[10]. The objective of the current research it to estimation radioactivity concentration in soil samplefrom eastern and northern regions of South Kordofan State, Sudan.

Materials and Methods

Study area: The research area was located in the South Kordofan State and lies between latitudes 29˚.32\ - 31˚.49\ E, and longitudes 11˚.47\ - 12˚.08\N.

Geological information of study area: The main topographical in the South Kordofan State are mountains known as Nuba Mountains' series. They are metamorphosed quartzofeldspathic younger granite rocks. Consist of compound rocks covered by unfolded sediments. The series belong to the alkaline post-orgonic (Figure-2)[11].

Sample collection and preparation: Sixty nine soil samples were taken from different locations around eastern and northern regions of South Kordofan State. At each sampling point, grass and trees leaves removed from the top of the soil surface before the soil was collected, using stainless steel sampler 15cma depth from the ground surface to get natural soil. Sampling locations were determined using GPS. The sample sizes were homogenized by passing through a 2mm test sieve. Samples were sealed in a 500 ml Marinelli beakers and left about 30 days to reach secular equilibrium between ^{238}U and ^{232}Th and their daughters.

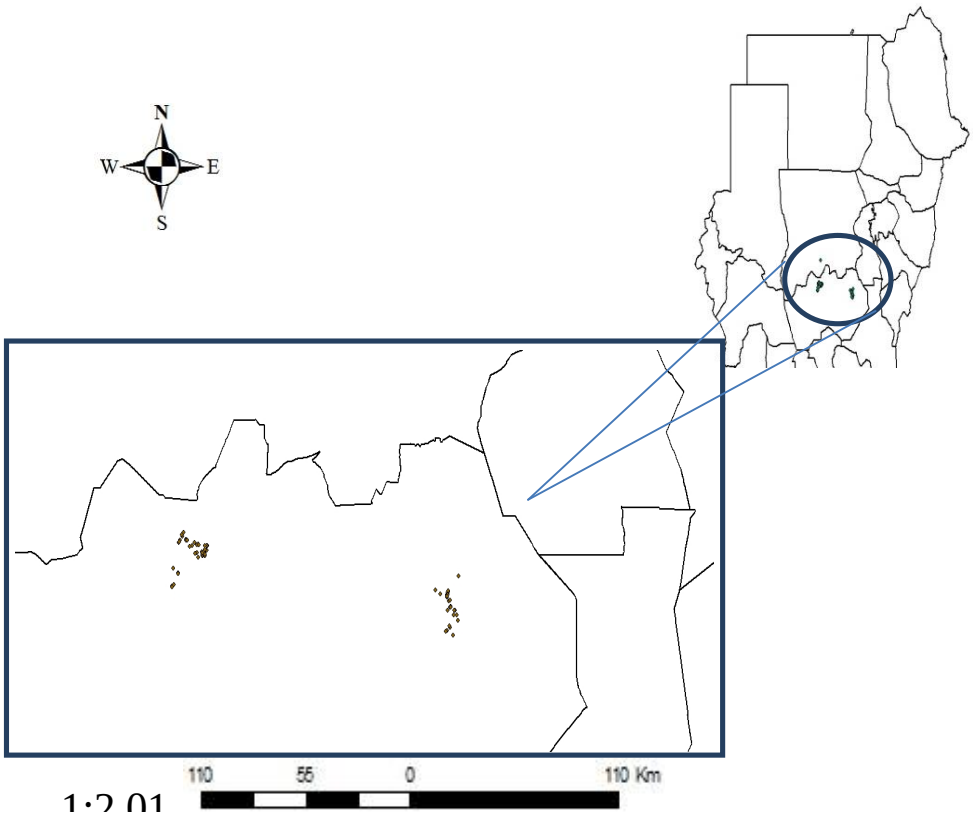

Figure-1
Map shows the sampling location

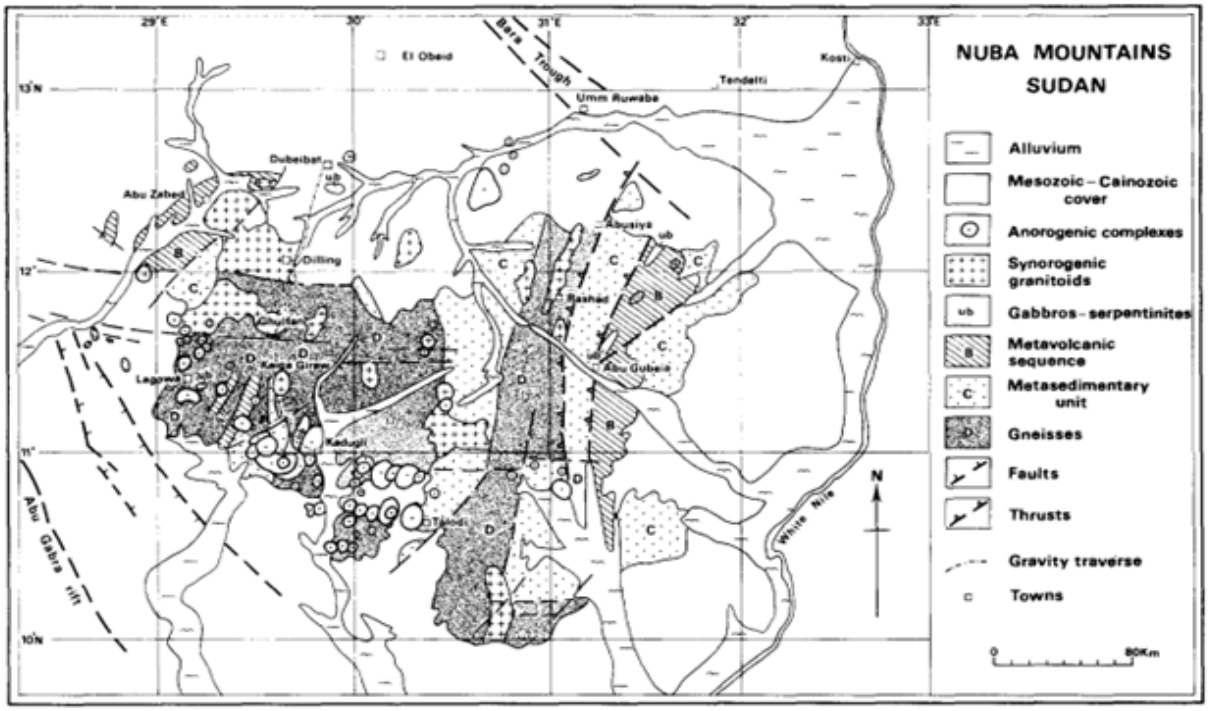

Figure-2
Geological map of study area

Sample measurements: The activity level of radionuclide ^{238}U, ^{232}Th and ^{40}K in soil samples were determined by γ-spectrometry equipped with NaI (Tl) detector. The samples were counted for three hours. Sample spectra were analyzed using winTMCA32 software package (provided by IAEA).^{238}U was determined via progeny photo peaks:^{214} Bi (609 Kev) and ^{214}Pb (352 Kev). ^{232}Th was analyzed through its progeny photo peak ^{212}Pb (238 Kev). The 1460 Kev gamma transition was used to determine^{40}K concentration.

The activity concentration of radionuclide in soil samples were identified using Equation (1):

$$A_c\ (Bq/kg\ ) = {}^{C_n}\!/\!_{P\gamma M\varepsilon} \quad (1)$$

Where: A_c is the activity distribution for element in the sample determined by Bqkg^{-1} C_n is the net count rate under the corresponding peak, $P\gamma$ is the absolute transition probability of the specific γ-ray, M is the mass of the sample (kg) and ε is the detector efficiency at the specificγ-ray energy.

Dose Calculation: The absorbed dose rate D (nGyh^{-1}) was determined from^{238}U, ^{232}Th and ^{40}K activity concentration using UNSCEAR dose rate conversion factor (0.462) for ^{238}U, (0.604) for ^{232}Th, and (0.0417) for ^{40}KnGy h^{-1} per Bqkg^{-1} [12]. The absorbed dose rate was calculated using equation (2), and the annual effective dose Equation (3)

D(nGyh^{-1})= A x dose rate conversion factor (nGyh^{-1} per Bqkg^{-1}) (2)

Where: D absorbed dose rate, and A activity concentration in BqKg^{-1}

The annual effective dose rate in air H (μSvy^{-1})was calculated using the conversion formula:

$$H = D(nGy/h) \times 24h \times 365.25d \times 0.2 \times 0.7SvGy^{-1} \times 10^{-3} \quad (3)$$

Where: 0.7 SvGy^{-1} is the conversion coefficient from absorbed dose in air to effective dose received by an individual, and 0.2 is the outdoor occupancy factor[1].

Results and Discussion

Table-1 shows that findings of activity level for radionuclide^{238}U, ^{232}Th and ^{40}K in soil samples from eastern and northern regions of South Kordofan State. The level ^{238}U, ^{232}Th and ^{40}K ranged from 15.44 to 868.24, 7.12 to 406.61and 226.67 to 2168.52BqKg^{-1} with average value of 108.82, 98.03and 1059.13BqKg^{-1}, respectively. The average level ^{238}U, ^{232}Th and ^{40}K are higher than international data 35, 30 and 400 Bqkg^{-1}, respectively published by UNSCEAR 2000. Themain factor influencing the level of terrestrial radionuclide in soil is the corresponding concentration in the soil forming rocks. Table-1and figure 3to 5, it is clear that highest value of ^{238}U was recorded in location S39, while the highest values of ^{232}Th and ^{40}K were recorded in location S6.

Table-2 shows Pearson Correlation Coefficient Test for activity concentration (Bqkg^{-1}) of ^{238}U, ^{232}Th and ^{40}K in soil samples from study area. The regression analysis has shown that significant correlation (P>0.01) was found between ^{232}Th and each of ^{238}U and ^{40}K (0.423 and 0.611) respectively, while no significant correlation was found between ^{238}U and ^{40}K.

The absorbed dose rate ranged from 23.87 to 586.06 nGyh^{-1}with average value of 153.65 nGyh^{-1}, the corresponding annual effective dose was be 29.29 to 719.23μSvy^{-1} with average value of 188.56μSvy^{-1} as shown in table-3. Due to UNSCEAR 2000 indicate, the dose rate from terrestrial gamma rays in normal conditions are approximately 57nGyh^{-1}, while the global rate annual effective dose is 70μSvy^{-1}, from obtained results in study area the absorbed dose rate and annual effective dose are exceed the normal level the reason could be geological features.

Figure-6 shows the main contribution to absorbed dose rate in air derived from ^{232}Th (38.54%). From different geographical regions in Sudan such as Jabel Mun200 nGyh^{-1} [13] and Sinnar 38.80nGyh^{-1} [14]. Also in other Countries, Turkey 67nGyh^{-1} [10] and Cyprus 14.7 nGyh^{-1}[15].

Table-1
Descriptive Statistical summary of ^{238}U, ^{232}Th and ^{40}Kactivity concentrations (BqKg^{-1}) in soil samples South Kordofan State

Parameter	**^{238}U**	**^{232}Th**	**^{40}K**
Average	108.82	98.03	1059.13
Standard Deviation	112.35	97.39	610.11
Minimum	14.55	7.12	226.67
Maximum	868.24	406.61	2168.52

Table-2
Pearson Correlation Coefficient Test estimating activity concentrations (Bqkg^{-1}) of ^{238}U, ^{232}Th and ^{40}K in soil samples

		^{238}U	^{232}Th	^{40}K
^{238}U	Pearson Correlation	1	.423(**)	-.135
	Sig. (2-tailed)		.000	.268
^{232}Th	Pearson Correlation	.423(**)	1	.611(**)
	Sig. (2-tailed)	.000		.000
^{40}K	Pearson Correlation	-.135	.611(**)	1
	Sig. (2-tailed)	.268	.000	
**. Correlation is significant at the 0.01 level (2-tailed).				

Table-3
Descriptive Statistical summary of ^{238}U, ^{232}Th, ^{40}K, absorbed dose rate(nGyh^{-1}) and annual effective dose (µSvy^{-1})

Parameter	^{238}U	^{232}Th	^{40}K	D(nGyh^{-1})	H(µSvy^{-1})
Average	50.27	59.21	44.17	153.65	188.56
Standard Deviation	51.91	58.83	25.44	104.20	127.87
Minimum	7.13	4.30	9.45	23.87	29.29
Maximum	401.13	245.59	90.43	586.06	719.23
Contribution% to the total dose rate	32.72	38.54	28.75		

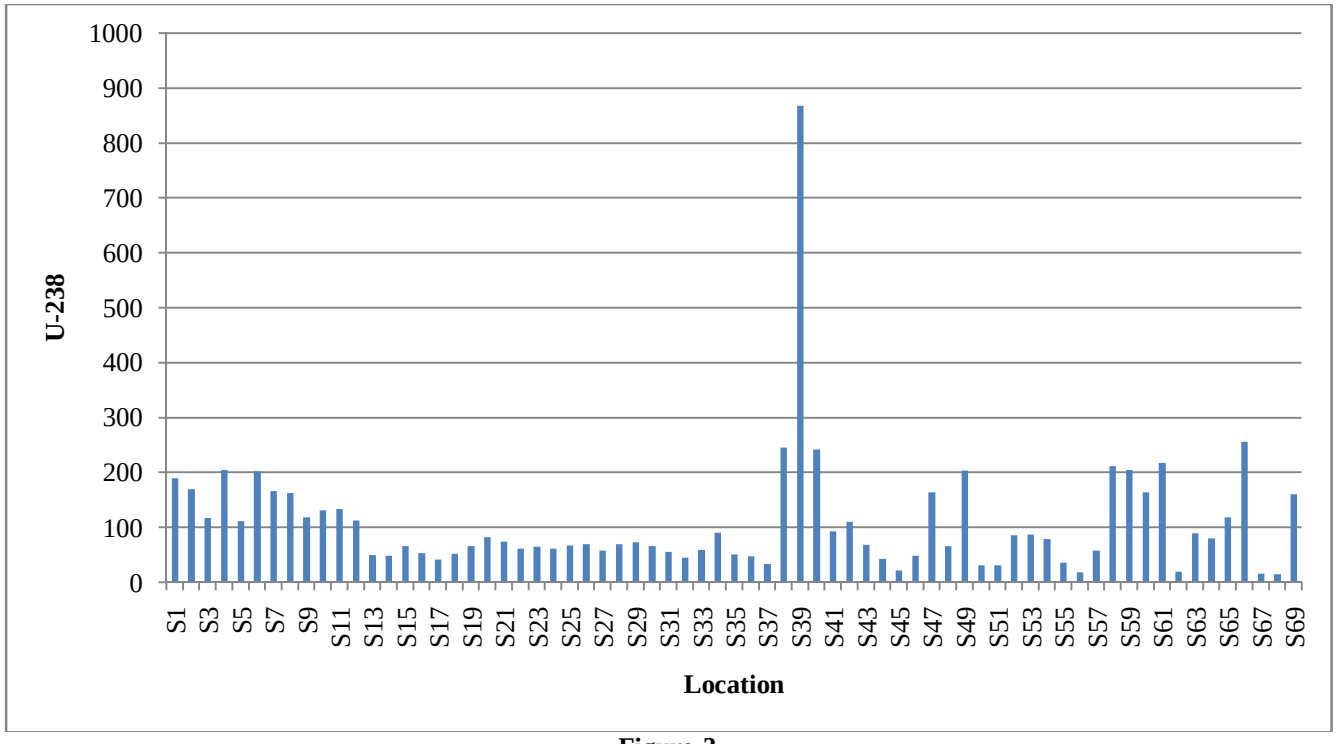

Figure-3
Location of ^{238}U distribution in soil samples fromeastern and northern regions of South Kordofan State

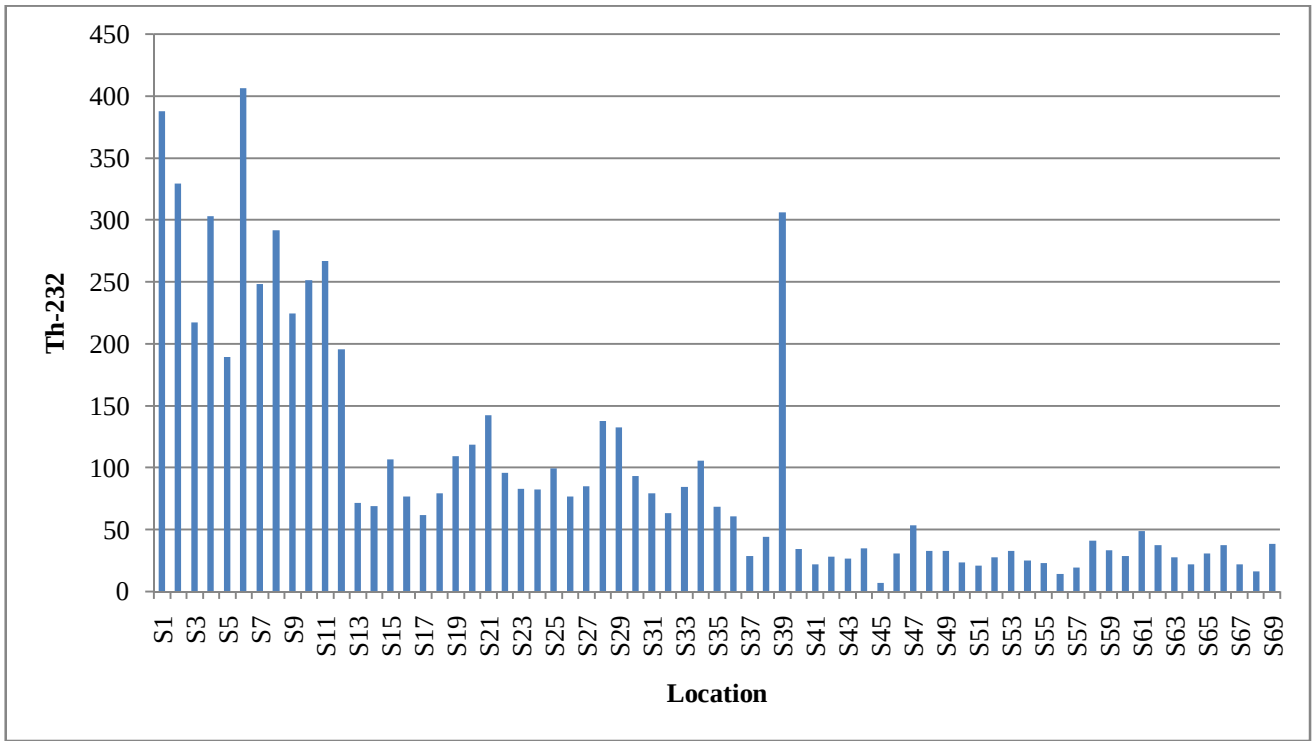

Figure-4
Location of ^{232}Th distribution in soil samples from eastern and northern regions of South Kordofan State

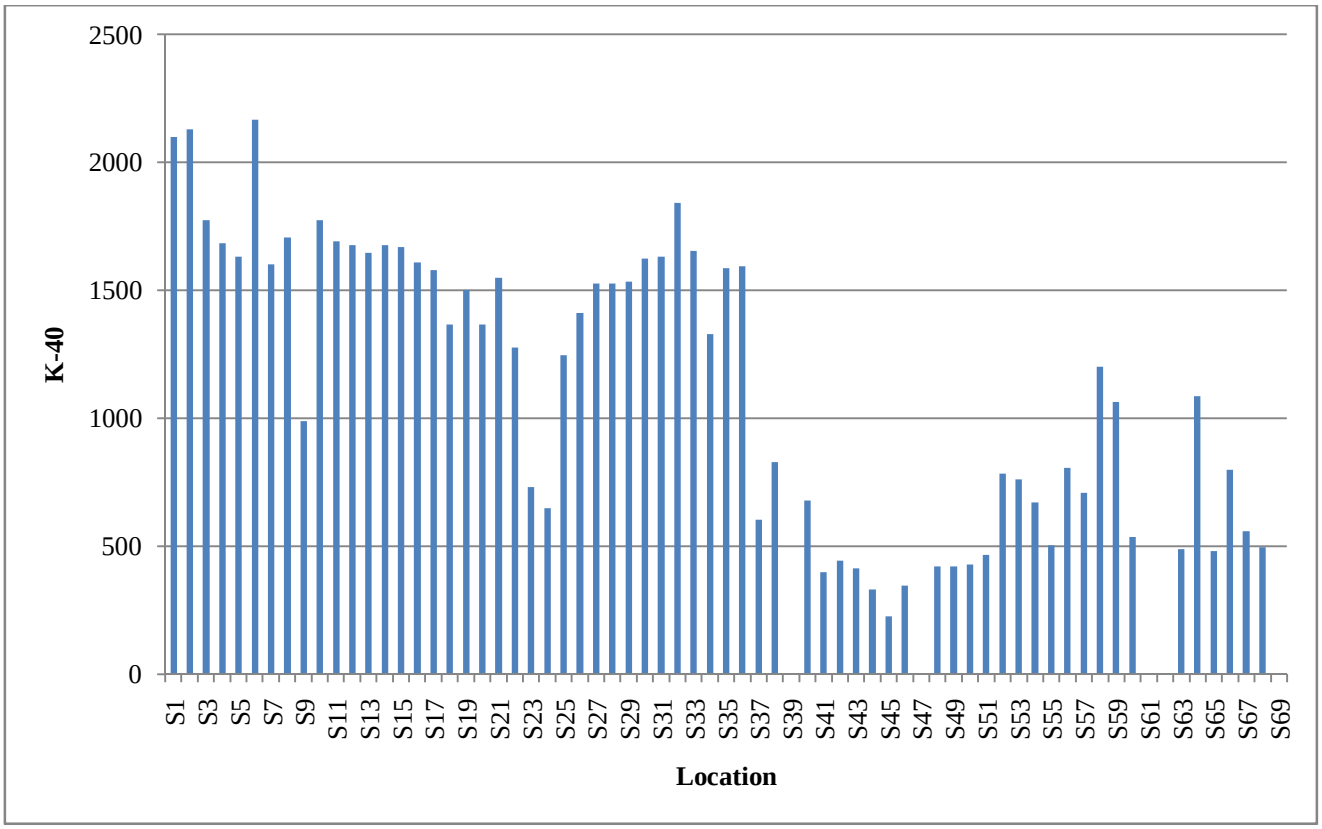

Figure-5
Location of ^{40}K distribution in soil samples from eastern and northern regions of South Kordofan State

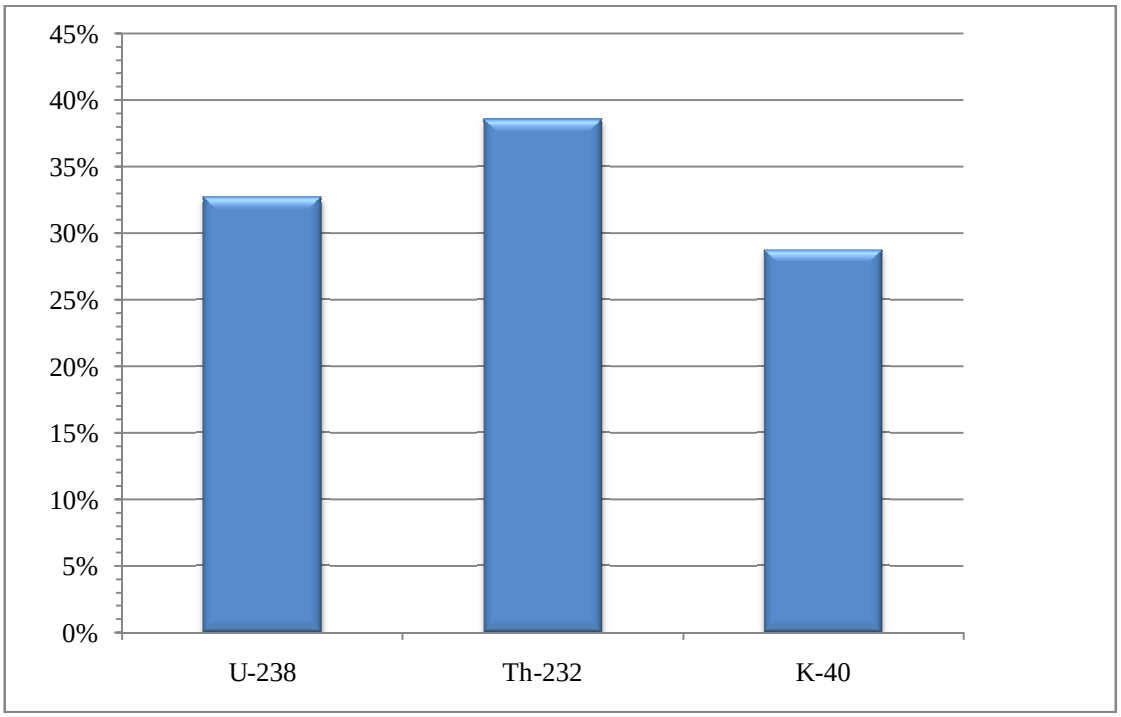

Figure-6
Relative contribution of ^{238}U, ^{232}Th and ^{40}K to the total absorbed dose rate in air as Calculated using UNSCEAR DRCF in soil samples

Conclusion

To sum up the following conclusion can be, i. The activity distribution of ^{238}U, ^{232}Th and ^{40}K in soil samples from eastern and northern regions of South Kordofan State were found to be relatively higher than UNSCER data. ii. There are significant correlation was found between ^{232}Th and each of ^{238}U and ^{40}K while no significant correlation was found between ^{238}U and ^{40}K.iii.The main contribution to overall absorbed dose in air derived from ^{232}Th. iiii.The absorbed dose rate andannual effective dose ineastern and northern regions of South Kordofan State is above worldwide average characteristics for high background areas

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