Assessment of Natural Radio activity in Rock Samples around South Kordofan State, Sudan

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Abstract

This study was conducted to assess gamma dose and radioactivity level in some areas in South Kordofan State. Activity level of ^{238}U, ^{232}Th and ^{40}K has been investigated by γ-ray spectroscopy equipped with NaI (Tl). The average concentrations were 282.76, 142.79and1081.50 $Bqkg^{-1}$, respectively. Moreover, the absorbed dose rate in air at height of 1m from the ground has been calculated, using four sets of dose rate conversion factors (DRCFs) and corresponding annual effective dose has been estimated. The average absorbed dose rate values obtained were found to be262.27, 222.39, 233.94 and 261.98$nGyh^{-1}$, respectively, and annual effective dose were found to be 321.87, 272.92, 287.10 and 321.52$μSvy^{-1}$, respectively, for DRCFs (SAITO, MCNP, GEANT and UNSEAR). However, the results indicate the radioactivity level in the surveyed area was higher than the global data reported in the UNSCEAR publications for normal background areas.

Keywords: Natural radioactivity, Rock, South Kordofan, Sudan.

Introduction

After the discovery of radioactivity in 1896 by A. H. Becquerel, There for numerous studies have been reported on radioactivity and radiation, this work presented to assess the natural radioactivity content of radionuclide some places in South kordofan State[1,2]. Natural radionuclides have been in existence in the environment since the formation of earth due to the long half-lives of radionuclides such as ^{238}U and ^{232}Th series and their decay products together with ^{40}K. These radionuclides presented from several media, including earth crust and rocks. The most abundant natural radioisotopes in the earth's surface are the ^{40}K, ^{232}Th and ^{238}U. From several studies on concentrations of radioisotopes in different types of rocks [3,4,5], it can be realized that, generally, the same type of rock presents a wide range of concentration values. Nevertheless, some trends can be found - for example, felsic igneous rocks have, in general, higher levels than sedimentary rocks. The radioactivity of rocks contributes to the external gamma dose rate that human receive from the environment. Therefore it has been important to evaluate the radioactivity of rocks and understand the dynamic of the radioisotopes in the natural environment, in the industrial processes and in the building practices. Uranium, thorium, and their decay products are radionuclides that represent a potential risk to human health due to the emission of ionizing radiation[5]. Radiation and radioactivity in the environment have natural and man-made sources. Natural radiation exposure represents the most significant part of the total exposure to radiation in the environment[6,7]

Materials and Methods

Study area: Area study is located in the South Kordofan State, and is bounded coordinates Latitudes 29˚.32ʽ and 31˚.49 Eʽ, and longitudes 11˚.47ʽ and 12˚.08ʽN

Sample collection and preparation: Twenty two rock samples taken randomly from study area. Each sample was then crushed and ground to fine powder and homogenized by passing through 2mm sieve. 500gm of each sample were sealed in Marinelli beaker for more than 30days before counting by gamma- ray spectroscopy to allow secular equilibrium between ^{238}U and ^{232}Th and their progenies.

Sample measurements: Activity of ^{238}U, ^{232}Th and ^{40}K in rock samples has been measured using γ-spectroscopy equipped with NaI (Tl) detector. The samples have been counted for three hours. Sample spectra were analyzed using win TMCA32 software package (provided by IAEA). ^{238}U has been determined by means of its progeny photo peaks: ^{214}Bi (609 Kev) and ^{214}Pb (352 Kev) ^{232}Th has been analyzed through its progeny photo peak ^{212}Pb (238 Kev). The activity of ^{40}K was measured by using 1460 Kev gamma line.

Dose Calculation: In this study the absorbed dose rate D ($nGyh^{-1}$) in air at a height of 1 m above ground surface has been calculated from activity concentration of ^{238}U, ^{232}Th and ^{40}K using different dose-rate conversion factors (DRCFS) as shown in (Table -2) [8] using formula (1).

$$D\ (nGyh^{-1}) = activity\ concentration\ (Bq\ kg^{-1})\ x\ DRCFs\ (1)$$

Where: DRCFs dose-rate conversion factors ($nGyh^{-1}$/ $Bq\ kg^{-1}$) as presented in Table-2

Total radiation risk to an individual organism is measured by annual effective dose (H), thus the estimated absorbed dose rate in air at 1 m height were converted into annual effective dose using the following formula:

$$H\ (\mu Svy^{-1}) = D\ (nGyh^{-1})\ x\ 24\ hx\ 365.25d\ x\ 0.2\ x\ 0.7\ Sv\ Gy^{-1}\ x\ 10^{-3}\ (2)$$

Where: The conversion coefficient from absorbed dose in air to effective dose received by an individual is 0.7 $SvGy^{-1}$ and the outdoor occupancy factor is 0.2[9].

Table-1
Activity distribution ($Bqkg^{-1}$) of gamma emitters from^{238} U, ^{232}Th and^{40} K in rock samples

Sample code	Location	^{238}U	^{232}Th	^{40}K
R70	Katla	38.75	37.101	ND
R71	Walaey	250.09	102.68	1360.05
R72	Kogoriea	18.64	19.11	90.67
R73	El karko	55.63	152.53	ND
R74	EL funda	117.43	134.16	1722.73
R75	El netil	77.59	92.19	1700.06
R76	Sallara	102.23	120.29	1866.29
R77	Hajer el sultan	91.08	99.69	1624.50
R78	El fous	110.51	111.30	1601.84
R79	Kakara	223.81	228.60	1586.72
R80	Kelara	79.29	101.56	1828.51
R81	Tondiya	99.01	163.02	1881.40
R82	Um takatik hill	685.45	246.96	1412.94
R83	Kurun hill	312.25	172.01	ND
R84	Kurun hill	653.08	218.86	ND
R85	Beside kurun hill	913.09	326.79	1866.29
R86	Beside kurun hill	792.05	258.96	1609.39
R87	Tumluk	119.14	29.23	ND
R88	Aryab	51.371	38.60	438.24
R89	Uro hill	551.85	198.62	1095.59
R90	Tirmi hill	93.18	10.87	521.35
R91	Uro market hill	785.18	278.44	1586.74
Mean		**282.76**	**142.79**	**1081.50**
SD		**294.96**	**90.28**	**766.05**
Min		**18.64**	**10.87**	**90.67**
Max		**913.09**	**326.79**	**1881.40**

ND: Not detectable

Table-2
Dose rate conversion factors (DRCFs) for some radionuclide used of absorbed dose rate (nGy h^{-1}/Bq kg^{-1})[8]

Nuclide	SAITO	MCNP	GEANT	UNSCEAR
^{238}U Series				
^{214}Pb	0.05460	0.04150	0.04342	
^{214}Bi	0.40100	0.33849	0.35554	
Total	**0.46300**	**0.38092**	**0.39996**	**0.462**
^{232}Th Series				
^{212}Pb	0.02770	0.01796	0.01917	
Total	**0.60400**	**0.51678**	**0.54373**	**0.604**
^{40}K	0.0417	0.03780	0.03995	0.0417

Results and Discussion

Table-1 presents the activity distribution of ^{238}U, ^{232}Th and ^{40}K in rock samples from different locations around South Kordofan State. Statistical summary (mean and range) of ^{238}U, ^{232}Th and ^{40}K were found to be 282.76±294.96 (18.64-913.09), 142.79±90.28 (10.87-326.79) and 1081.50±766.05 (90.67-1881.40) Bqkg^{-1}, respectively, as shown in Table-1. In these calculations, standard deviation values indicate that the activity concentration of primordial radionuclides are highly scattered

which indicates that the geological features in the study area are not much differ. The absorbed dose rate average value ranged from 222.27 to 261.98 nGyh^{-1}and the corresponding annual effective dose average value ranged from 272.92 to321.87µSvy^{-1} as shown in table-3.According to UNSCEAR 2000 reported data, the absorbed dose rate from primordial gamma rays in normal conditions are 57 nGyh^{-1} and annual effective dose is70µSvy^{-1}in study area in South Kordofan State the absorbed dose rate and annual effective dose are higher than normal level this converted to geological features. Upon comparing the values obtained, it is obvious that all the currently available DRCFs which have been used in this study give values with unremarkable differences as one way ANOVA test showed no significant differences (P>0.05), see Table -4. However, the all sets of DRCFs seem as if they are two families see table-3 for SATIO and UNSCEAR formulas on one hand as they display value (262.27, 261.98) nGyh^{-1}with corresponding annual dose of (321.87, 321.52) µSvy^{-1}, whereas Monte Carlo based for formulas namely MCNP and GAINT constitute one family as it is seen from the average value (222.39, 233.94) nGyh^{-1} with corresponding annual dose of (272.92, 287.10) µSvy^{-1}. It should be noted that in the UNSCEAR reported, dose rate conversion factors are taken from Saito and Jacob (1995), which are 10-20% higher than the more accurate values obtained recently by various Monte Carlo techniques[8]and that apparent from these results. Estimation of the relative contribution of the ^{238}U, ^{232}Th and ^{40}K to the total absorbed dose in air revealed that the major contribution comes from ^{238}U (49.92%) see Figure-1

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

DRCFs	^{238}U	^{232}Th	^{40}K	nGyh^{-1}	µSvy^{-1}
SAITO					
Mean ±SD	130.92 ±136.57	86.25 ± 54.53	45.10± 31.94	262.27±197.13	321.87 ±241.93
Range	8.63 - 422.76	6.56 - 197.38	3.78 - 78.45	23.96 - 697.96	29.40 - 856.57
Contribution %	49.92	32.89	17.20		
MCNP					
Mean ±SD	107.71 ±112.36	73.80 ± 46.65	40.88 ± 28.96	222.39±165.04	272.92 ±202.54
Range	7.10 - 347.81	5.62- 168.88	3.43 - 71.12	20.40 - 587.24	25.04 - 720.68
Contribution %	48.43	33.18	18.38		
GEANT					
Mean ±SD	113.09 ±117.97	77.64± 49.09	43.21 ± 30.60	233.94±173.47	287.10 ±212.89
Range	7.46 -365.20	5.91 -177.68	3.62- 75.16	21.47 - 617.44	26.35 - 757.75
Contribution %	48.34	33.19	18.47		
UNSCEAR					
Mean ±SD	130.63±136.27	86.25 ± 54.53	45.10 ± 31.94	261.98±196.85	321.52± 241.58
Range	8.61- 421.85	6.56 - 197.38	3.78- 78.45	23.94 - 697.05	29.38 - 855.45
Contribution %	49.86	32.92	17.22		

Table-4
One way ANOVA test to examine differences in absorbed dose rate (nGyh^{-1}) of ^{238}U, ^{232}Th and ^{40}K in rock samples

		Sum of Squares	df	Mean Square	F	Sig.
	Factor DRCFs methods					
^{238}U	Between groups	9453.373	3	3151.124	0.198	0.898
	Within groups	1338968.860	84	15940.105		
	Total	1348422.233	87			
^{232}Th	Between groups	2602.628	3	867.543	0.329	0.804
	Within groups	221183.379	84	2633.135		
	Total	223786.007	87			
^{40}K	Between groups	264.643	3	88.214	0.092	0.964
	Within groups	80134.317	84	953.980		
	Total	80398.960	87			
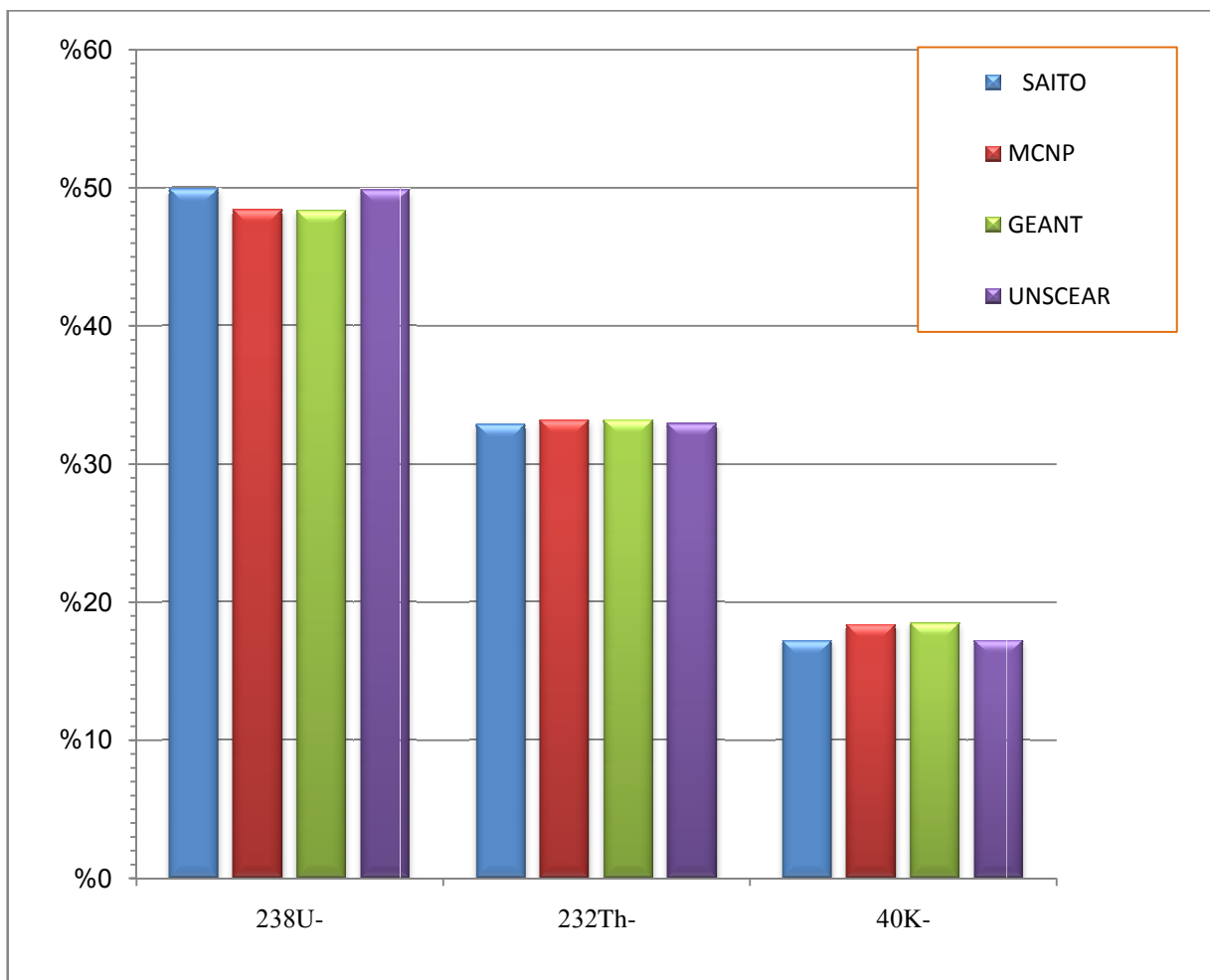
Figure-1
Relative contribution of ^{238}U, ^{232}Th and ^{40}K to the total absorbed dose rate in air as calculated using different DRCFs in rock samples

Conclusion

The absorbed dose rate and annual effective in this study area were found to be higher than the worldwide average. There are no significant differences between ^{238}U, ^{232}Th and ^{40}K. The major contribution to the total absorbed dose in air is comes from ^{238}U.

Acknowledgment

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