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Natural Radioactivity Concentration and Radiological Assessment in Soil Samples Around Abu Jubayha, Eastern Nuba Mountain

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Abstract: The study aimed to determine the radioactivity concentration and radiological assessment in Soil samples around Abu Jubayha, Eastern Nuba Mountains was made by gamma spectrometry technique equipped with NaI (Tl). The result of activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were varied from 23.58 ±7.86 (18.02-29.14), 36.14 ± 5.17 (32.48 -39.79) and 381.88± 127.43 (291.78 - 417.99) Bqkg^{-1} respectively. Absorbed dose rate and annual effective dose were estimated to evaluate radiological hazards and were varied from 39.47±8.6 (33.38-45.55) nGyh^{-1}and 38.43±10.56 (40.97-55.9)µSvy^{-1}, respectively .Upon comparing the results with global data, they were found to be within the recommended limits. The result will be serving as a base line for future studies. GIS apocalyptic map was originated and has shown that there were some hot spots with high activity distribution and concentrations of the measured radionuclide and similarly Dose Rate.

Keywords: Natural Radioactivity, Radiological Assessment, Soil Samples and Gamma Spectrometry Technique NaI (Tl)

INTRODUCTION

The radioactivity on the environment is mainly due to extra-terrestrial and terrestrial radionuclide, this type of radiation is produced from radionuclide as Uranium (^{238}U), Thorium (^{232}Th), and radioactive families together with Potassium (^{40}K) [1].Globally the terrestrial radiation level was considerable variation in their soil and rock composition with each region in the world and depends on geological and geographical conditions [2]. This list of radionuclide is responsible for the majority of radiation exposure of the vast majority of people.

Soil is regarded as the central source of artificial radionuclides from precipitation, and it acts as a medium of migration and transferring of this radionuclide's to the biological systems. For this purpose it is important to investigate and assess the doses resulting from the radionuclide concentration in soils its impact on the humans and the environment [3]. Recently, in Sudan, mid 1980 started national strategic programmer on environmental radioactivity monitoring to establish guidelines documentation for radiation protection gaudies to be as reference for any radiological impacts [4] .However, several researches ware evaluated at different location in Sudan soil to contribute national program [4−9]. For this purpose, the study was extended other studies to evaluate natural radioactivity distribution and assess dose in soil. Moreover, this assessment also provides a base line date for estimating the change in environmental radiation.

MATERIALS AND METHODS

Geological Setting

The area under consideration is Abu Jubayha region, in eastern Nuba Mountains, South Kordofan State lies between latitudes 10˚.92′ and 11˚.82′ and longitudes 30˚.38′ and 32˚.40′ as shown in Fig (1), the area studied was lies within rich savanna belt , which characterized by seasonal rain fall, from June to October . Geologically the Abu Jubayha region is built of a complex basement rocks surrounded by a cover volcano-sedimentary series of rocks (quartz-sericite schist, graphite, and dolomitic marbles), in addition granitic and syenitic in North and East direction of study area (see the map Fig-2). Moreover, Soil types in the investigated filed categorized sand (67%), sandy loam (15%) in the Northern part, and heavy cracking clay (gray to black) (18%) in the south.

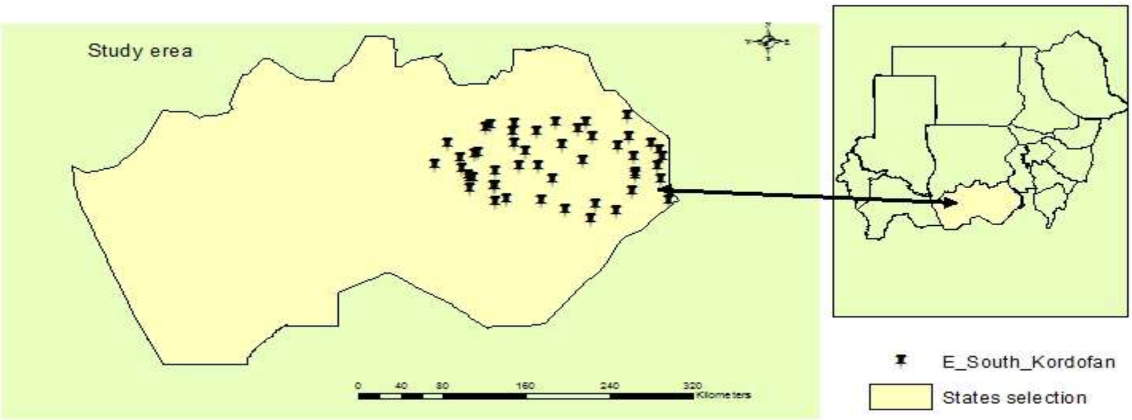

Fig-1: Map of Sudan showing Sampling location, Nuba Mountains, Abu Jubayhah region

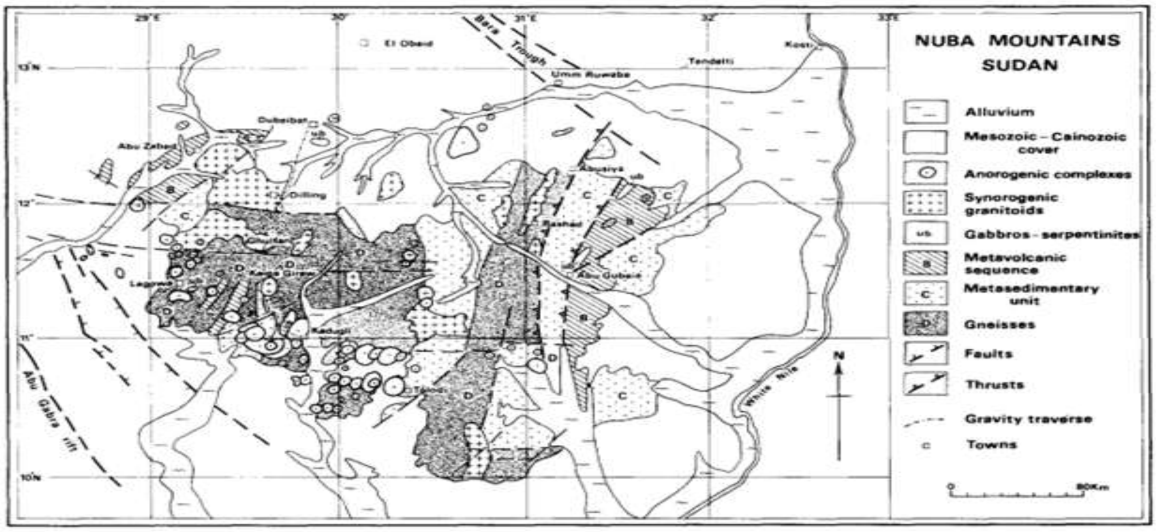

Fig-2: Geological map of study area.

Sample Collection, Preparation and Measurement

A total 48 soil samples were collected from various sites along the Abu Jubayha region using soil – sampler at depth 15 to 25 cm and coordinates were recorded using GPS. After collection Samples were crushed to fine powder using ball mills, and were kept in sealed 500ml plastic containers and stored for one month to allow ^{238}U and ^{232}Th to reach equilibrium with its progeny before analysis of gamma ray spectrometry.

The sample was measured for 10800scecond using the sodium iodid detector and each measured gamma‾ray spectrum have been analyzed by the software program win TMCA32. In addition the detector has a resolution of 6.7% for the 1332 Kev gamma line of ^{60}Co. The ^{226}Ra concentration was determined from the ^{214}Pb (351.9 keV) and ^{214}Bi (609.2 keV),and that of ^{232}Th was determined form concentration of ^{212}Pb(238.6 keV) , whereas ^{40}Kconcentrations were measured from The transition lines of (1.460KeV)gamma line.

Radiological assessment factors

Absorbed Dose Rate

Based on measured radionuclide concentrations in soil samples the absorbed radiological dose (nGyh^{-1}) was determined using the following simple equation (1):

$$D\ (nGyh^{-1}) = 0.427S_{Ra} + 0.662\ S_{Th} + 0.043S_{K} \qquad (1)$$

Where D (nGyh^{-1}) represents the total air absorbed dose rate due to the specific activity concentrations (S_{Ra}, S_{Th}, and S_k) of ^{226}Ra , ^{232}Th and ^{40}K , respectively, at 1.0 m above the ground surface[2].

Annual Effective Dose

To estimate the annual effective dose, H (μSvy^{-1}), was calculated according to following Eq (2):

H (μSvy^{-1}) = D ($nGyh^{-1}$) x 24 h x 365.25d x 0.2 x 0.7 $SyGy^{-1}$ x 10^{-3} (2)

Where: 0.7 is quotient of annual effective dos rate to absorbed dose rate in air for environmental exposures to gamma rays and 0.2 is the outdoor occupancy factor [10].

Calculation of the radiation hazard parameter

To estimate of the gamma radiation hazard teams (radium equivalent activity (Ra_{eq}) in $Bqkg^{-1}$, external hazard index (H_{ex}), Internal hazard index (H_{in}) and Gamma index(Iγ) associated with natural radionuclide's were calculated based on radiation hazard indexes from the following criterions (3,4,5& 6)

$$Ra_{eq}=A_{Ra}+1.43A_{Th}+0.077A_k \quad (3)$$

$$H_{ex}=\frac{A_R}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \leq 1 \quad (4)$$

$$H_{in}=\frac{A_R}{185}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \leq 1 \quad (5)$$

$$I\gamma=\frac{A_R}{150}+\frac{A_{Th}}{100}+\frac{A_K}{150} \leq 1 \quad (6)$$

RESULTS AND DISCUSSION

Table-1: Average radioactivity concentrations ($Bqkg^{-1}$) of ^{226}R, ^{232}Th, and ^{40}K in soil samples around abujubayha, Eastern Nuba Mountains.

Location No	Lat.	Long.	Alt.	^{226}Ra	^{232}Th	^{40}K
1	11.90	32.04	449	18.02	32.48	291.78
2	11.62	32.25	405	14.42	30.45	274.61
3	11.55	32.32	392	15.92	21.52	257.45
4	11.49	32.34	393	19.22	25.99	248.87
5	11.39	32.30	394	18.32	23.14	223.12
6	11.25	32.32	394	19.22	24.77	266.03
7	11.68	32.06	432	17.72	22.33	266.03
8	11.49	32.09	418	19.22	28.83	257.45
9	11.29	32.11	404	18.62	20.3	334.68
10	11.12	32.08	404	20.73	16.24	274.61
11	11.04	32.40	393	21.03	33.3	223.12
12	10.92	31.95	414	26.13	48.72	273.75
13	11.00	31.76	443	21.93	27.61	248.87
14	11.44	31.65	542	24.63	36.54	171.63
15	11.68	31.74	535	29.44	39.79	334.68
16	11.85	31.68	559	29.44	41.42	283.19
17	11.59	31.96	450	23.73	32.48	308.94
18	11.32	32.11	403	26.43	32.08	351.85
19	11.38	31.27	564	30.34	41.01	326.1
20	11.04	31.30	529	29.14	41.42	351.85
21	10.93	31.50	451	28.54	35.33	377.59
22	10.84	31.72	429	24.93	22.74	283.19
23	11.62	31.07	651	33.04	24.77	429.08
24	11.74	31.26	764	29.14	41.82	334.68
25	11.85	31.42	1079	28.24	40.2	308.94
26	11.77	31.61	556	28.24	31.27	308.94
27	11.61	31.48	616	27.33	42.63	326.1
28	11.81	30.86	692	19.53	24.77	205.96
29	11.74	31.06	761	29.14	37.76	379.31
30	11.52	30.75	663	21.93	34.92	291.78
31	11.26	30.71	743	26.73	40.2	454.83
32	11.19	30.88	626	26.73	20.3	334.68
33	11.05	31.00	578	29.44	40.6	317.52
34	11.02	30.90	714	30.04	39.39	369.01
35	11.16	30.68	722	29.74	41.82	386.17
36	11.47	30.60	717	27.03	30.05	360.43

37	11.30	30.66	749	27.94	40.6	254.02
38	11.34	30.90	653	23.43	26.39	335.54
39	11.39	31.10	608	29.44	37.36	240.29
40	11.36	30.61	758	27.64	34.92	314.95
41	11.62	30.49	727	29.44	41.82	358.71
42	11.26	30.68	761	27.94	28.42	314.95
43	11.19	30.90	627	23.43	43.45	325.24
44	11.25	31.39	534	26.73	36.14	345.84
45	11.53	31.17	605	27.03	33.3	411.92
46	11.40	30.38	704	25.83	41.82	435.09
47	11.51	30.72	697	29.14	39.79	471.99
Max				**29.14**	**39.79**	**471.99**
Min				**18.02**	**32.48**	**291.78**
Average				**23.58**	**36.14**	**381.88**
STD				**7.86**	**5.17**	**127.43**

Table-2: Absorbed dose from gamma radiation, annual effective dose, Radium equivalent activity (Ra_{eq}), Gamma index (Iγ), external and internal hazard index calculated for soil samples round in soil samples round abu Jubayha , Eastern Nuba Mutations.

parameter	$nGyh^{-1}$	μSvy^{-1}	Ra_{eq}	Iγ	H_{ex}	H_{in}
Mam	**45.55**	**55.9**	**102.96**	**0.7**	**0.38**	**0.34**
Min	**33.38**	**40.97**	**74.93**	**0.51**	**0.27**	**0.24**
Average	**39.47**	**48.43**	**88.94**	**0.6**	**0.32**	**0.29**
STD	**8.6**	**10.56**	**19.82**	**0.13**	**0.08**	**0.07**

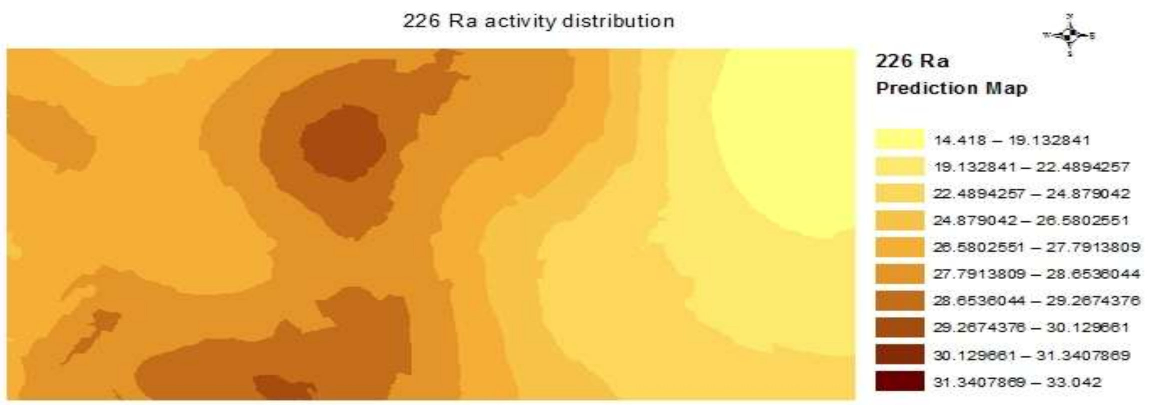

Fig -3: GIS Prediction map for activity concentration of ^{226}Ra

Fig-4: GIS Prediction map for activity concentration of ^{232}Th

Fig -5: GIS Prediction map for activity concentration of ^{40}K

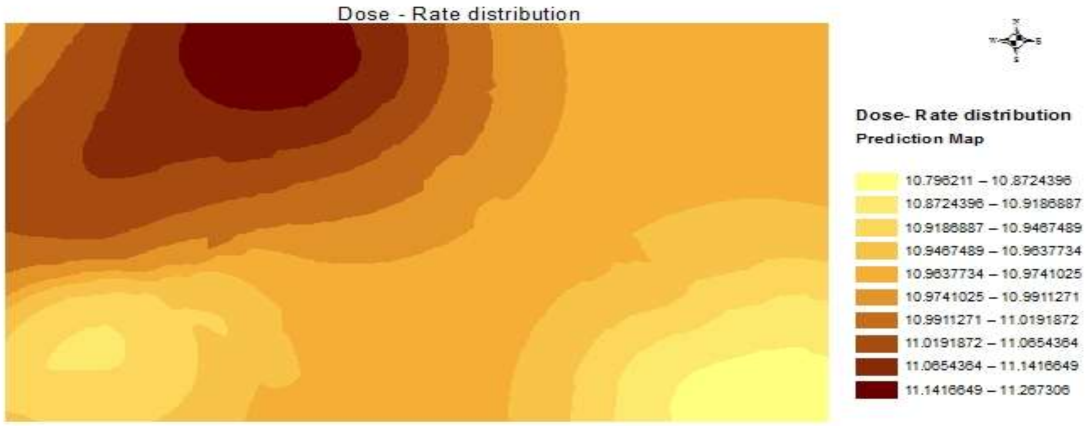

Fig-6: GIS Prediction map for activity concentration of Absorb Dose Rate

Table-1 listed the activity concentrations of ^{226}Ra, ^{232}Th and^{40}K in soil samples from different locations around abu Jubayha reported in BqKg^{-1}and the study was considered various radiological parameter. Statistical summary (mean and range) of ^{226}Ra, ^{232}Th and ^{40}K were found to be 23.58 ±7.86 (18.02-29.14), 36.14± 5.17 (32.48 -39.79) and 381.88± 127.43 (291.78 -417.99) Bqkg^{-1}, respectively, as shown in Table-1. Also The study was reported highest activity concentrations of ^{232}Th (51.87), ^{226}Ra (39.79) and ^{40}K (471.99) Bqkg^{-1} , were measured in location (No.47),the reason could be attributed to geological structures. Geologically the area under investigation is characterized by complex sedimentary, basement rocks, and granite. The obtained results are comparable to the worldwide average concentration of these radionuclide ^{226}Ra, and ^{40}K in soil samples was indicated less then worldwide average which are 35,400 Bq.Kg^{-1} , respectively .While ^{232}Th is slightly greater then globe average which is 30 Bq.Kg^{-1} (UNSCEAR, 2000). However, the obtained results were indicated lower than the corresponding global values categorized in the UNSCEAR documentation for normal background areas. GIS predictive mapping for activity concentration of ^{226}Ra,^{232}Th and ^{40}K were listed in Figures(3,4, and5) respectively, and reported that there were some hot spots with high activity distribution and concentrations of the measured radionuclide and displayed the highest values indicating the trend of increasing from the West to North West.

The radiation absorbed dose and annual effective dose was estimated from measurement of activity concentration in soil and was reported in Table-2 , shows that the values ofabsorbed dose rate ,annual effective dose were varied from39.47±8.6(33.38-45.55)nGyh^{-1}and 38.43±10.56 (40.97-55.9)µSvy^{-1}, respectively. However, comparing the results with world wide data, the obtained values far below the reported the UNSCEAR2000 (60nGyh^{-1}) and ICRP(1µSvy^{-1}) . In addition ,this data, similarly results were report from national researcher 29.61 nGyh^{-1}North Kordofan [7] ,North Sudan 57nGyh^{-1} [11] ,Elgash area 37.5 nGyh^{-1} [12] , Sinnar 38.80 nGy h^{-1} [4] , Jabel Mun 200 nGyh^{-1} [13], Kurun190 nGyh^{-1}and Uro1900 nGyh^{-1}[14]. Fig-5 as shown absorbed dose rate in air (nGyh^{-1}) originated GIS prediction map for were reflects the trend of increasing North direction. Therefore Radium equivalent activity (Ra_{eq}), Gamma index (Iγ) associated for terrestrial gamma rays exposure due to radionuclide's in the soil estimated and were found to vary between 88.94±19.82(74.93-102.96) and 0.60±0.13(0.51-0.70)µSvy^{-1}respectively , and were reported lower than the global average of 370 Bqkg^{-1} and ≤ 1 µSvy^{-1}(UNSCEAR 1982)and (NEA-OECD, 1979), respectively. So the external hazard indices and internal hazard indices calculated and were ranges from 0.32±0.08 (0.27-0.38) and 0.29±0.07 (0.24-0.34), respectively. Also results shown to be acceptable limits recommended by (ICRP, 1991 and UNSCEAR, 2000).

CONCLUSION

Based upon the results reported in this study the following conclusion:

- Activity concentration of Natural radionuclide's ^{226}Ra, ^{232}Th, and ^{40}K were assess by gamma-ray spectrometry system, and the results shown lower than the allowable limits recommended by UNSCEAR Publication
- the obtained results of gamma dose rate , annual effective dose , Radium equivalent activity (Ra_{eq}), Gamma index(Iγ) external and internal hazard index were found lower then recommended safety limits

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