IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 9, Issue 4 Ver. III (Jul. – Aug. 2017), PP 35-39
www.iosrjournals.org

Natural Radiation Map of the Sudan

*Magdi Hassan Saad[1, 2]
[1]- *Department of Physics, Faculty of Science, Taibah University - Yanbu Branch, KSA*
[2]- *Department of Physics, Sudan University of Science & Technology, Khartoum, Sudan*
Corresponding Author: Magdi Hassan Saad[1]

Abstract: *The aim of this study was to investigate the distribution of natural radiation in Sudan by evaluating the level of natural radioactivity and calculating the external exposure due to radiation from the ground. Surface soil samples were collected from different states in Sudan and their activity concentrations were measured by gamma spectrometer system with a high-purity germanium detector. This allowed us to construct a contour map of the radiation level in Sudan where the highest exposure was found at South Kurdufan state with an average 81 nGy.h^{-1}, and the lowest exposure was found at Nahr El-Nile state with an average 25 nGy.h^{-1}. The exposure was successfully extrapolated to cover the rest parts of Sudan.*

Keywords*: Environmental, Natural Radioactivity, Annual exposure, External exposure.*

Date of Submission: 23-02-2017 Date of acceptance: 05-08-2017

I. Introduction

People are exposed to the natural gamma radiation of radionuclides emitting uranium, thorium and potassium in the natural environment. In the vicinity of the Earth's natural environment, radioactivity is widespread and exists in different geological formations. Therefore, man must be aware of the effects of natural radiation because they occur naturally and induced radioactive elements. Measurement of radioactivity in nature causes radiation risk assessment [1]. About 57% of natural radiation exposure is due to U-238 series [2, 3]. Local organizations such as the International Commission on Radiological Protection and the United States Environmental Protection Agency (USEPA) have set standards and legislation to minimize such exposure [4, 5].

As with regard to such kind of investigation in the Sudan, Mukhtar *et al* [6] concluded that the level of natural radioactivity background at Miri area was in the range of 3 - 11 times the normal one. On the other hand, Inaam [7] reported that the highest counts reached in Nuba mountains was about 6000 CPM where in some places was elevated slightly from the normal levels. More studies was carried out by Nour and Saam [6, 8]. However, and according to our knowledge, systematic study of the radiation level throughout the whole region of Sudan is lacking. Thus, this work report on the radiation level measurements in Sudan aiming at the identification of the maximum radiation spots and at the production of radiation map for the whole country. Surface soil samples were collected from different states in Sudan and their activity concentrations were measured by gamma spectrometer system with a high-purity germanium detector.

Sample collection and preparation:

Fig. 1 an 2, respectively, show the maps for the 15 states in Sudan and the corresponding geological landscapes. Soil samples were collected from the 15 states including surface and sub-surface soil samples (10 cm in depth) from various locations. Soils in Sudan vary according to the geological formation and characteristics of the soil types. For North and Nahr El-Nile states they represent sand soil, the soils in the Red Sea and Darfur states are mostly rocky and mountains, and the Kurdufan state has both sand and rocks. Soil in Sinnar and Blue Nile states is muddy. The mass of the collected sample was around 1 kg and kept in polyethylene bags for analysis in the laboratory. In the laboratory the samples were air-dried, ground into fine powder, sieved at 2 mm mesh and stored in Marinelli beaker [9] for 28 days before analysis.

Experimental method

The collected samples measured for their ^{226}Ra, ^{232}Th and ^{40}K contents using a high- purity germanium (HPGe) detector gamma –ray spectrometr system, shield by 5cm thickness of cylindrical lead, with inner concentric thin cylinders thickness 2mm of Cd, Cu, Fe and Al, to reduce the radiation background. For the system energy and efficiency calibration ^{22}Na, ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs and ^{152}Eu IAEA gamma standard sources were used in the geometry of the samples measurement in Marinelli beakers. Sample was counted for 6 hours after equilibrium and the spectra were saved in a computer and then analyzed using Genie-2000 gamma analysis software. ^{238}U and ^{232}Th are not gamma-emitters they measured indirectly through from their daughters: ^{226}Ra descendant of ^{238}U, was measured through ^{214} Pb (emitting gamma-rays of 295 and 352 keV), ^{232}Th through ^{212}Pb (emitting 239 keV gamma-rays). ^{40}K was measured directly from the emitted gamma-ray of 1461 keV, finally the activity concentration of each radionuclide measured in Bq/kg

II. Results And Discussion

The activity concentration ranges for ^{40}K, ^{232}Th and ^{226}Ra from soil samples were as follows:
In North and Nahr El-Nile states were (469-108) $Bq.kg^{-1}$, (19-7) $Bq.kg^{-1}$ and (11-3) $Bq.kg^{-1}$, respectively. While that in Darfor were (719-79) $Bq.kg^{-1}$, (41-3) $Bq.kg^{-1}$ and (85-11) $Bq.kg^{-1}$ respectively. In Kurdufan state they were as high as (1201-108) $Bq.kg^{-1}$, (69-9) $Bq.kg^{-1}$ and (78-9) $Bq.kg^{-1}$ respectively. In Sinar, Blue Nile and El-Gadarif states they were (393-11) $Bq.kg^{-1}$, (45-17) $Bq.kg^{-1}$ and (50-10) $Bq.kg^{-1}$, respectively. In khartoum and El-Gazira states they were (339-111) $Bq.kg^{-1}$, (25-12) $Bq.kg^{-1}$ and (22-11) $Bq.kg^{-1}$ respectively. For the Red Sea state they were (922-120) $Bq.kg^{-1}$, (47-11) $Bq.kg^{-1}$ and (85-11) $Bq.kg^{-1}$ respectively.

It is clear that the lowest exposure was acquired from North and Nahr El-Nile states. The reason for that can be seen from the geological landscape of this region (Fig. 2) which is dominated by sand soil. In contrast the mountain area of Darfor and Kurdufan state (Fig. 2) has the highest exposure.

At 1 m height above the ground the absorbed dose rate in air D (nGy/h) for population living in the studied areas was calculated using the following equation below [10] and mapped in Fig. 3 using Surfer 10 software:

$$D\ (nGyh^{-1}) = 0.461(A_{Ra}) + 0.623(A_{Th}) + 0.0414(A_K) \qquad (1)$$

where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively [11, 12].

The annual effective dose was calculated using the equation:

$$H = D\ (nGy/h) \times 0.7\ (Sv/Gy) \times 8760(h/y) \times 0.2 \qquad (2)$$

while the equivalent activity of the Ra was calculated mathematically by the formula:

$$Ra_{eq} = (A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \qquad (3)$$

The index of the external radiation due to the radionuclides was measured by the equation:

$$H_{ex} = A_{Ra}/ 370 + A_{Th}/ 259 + A_K/ 4810 \qquad (4)$$

The calculated quantities D, H, Ra_{eq}, and H_{ex} are tabulated in Tables 1 - 4, respectively. These quantities were measured for different states in Sudan as indicated in the Tables 1 - 4. To our knowledge, similar systematic measurement of these quantities in Sudan are lacking. Furthermore, the extensive acquisition of these data enabled us to extrapolate the exposure level throughout the country as shown by the contour plot of the quantity D in Fig. 3.

III. Conclusion:

This report investigated the distribution of natural radiation in Sudan by evaluating the level of natural radioactivity and calculating the external exposure due to radiation from the ground. Surface soil samples were collected from different states in Sudan and their activity concentrations were measured by gamma spectrometer system with a high-purity germanium detector. This allowed us to construct a contour map of the radiation level in Sudan where the highest exposure was found at South Kurdufan state with an average 81 $nGy.h^{-1}$, and the lowest exposure was found at Nahr El-Nile state with an average 25 $nGy.h^{-1}$. The exposure was successfully extrapolated to cover the rest parts of Sudan.

References

[1] UNCEAR, Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, 2000.

[2] UNSCEAR, Effects of ionizing radiation: UNSCEAR 2006 Report to the General Assembly, with scientific annexes. Vol. 2. 2009: United Nations Publications.

[3] Clarke, R. and T. Southwood, Risks from ionizing radiation. Nature (London), 1989. **338**(6212): p. 197-198.

[4] Saleh, H. and M.A. Shayeb, Natural radioactivity distribution of southern part of Jordan (Ma′ an) Soil. Annals of Nuclear Energy, 2014. **65**: p. 184-189.

[5] Hammond, D.S., et al., Causes and consequences of a tropical forest gold rush in the Guiana Shield, South America. AMBIO: A Journal of the Human Environment, 2007. **36**(8): p. 661-670.

[6] Osman Mustafa, M., Environmental Study for Radionuclides at Miri Lake Area. 2000, uofk (PhD thesis).

[7] Inaam, A., Investigation on the use of Nuba mountains phosphate rocks in agriculture. 1993, M. Sc. Thesis, University of Khartoum, Sudan.

[8] Sam, A.K., Radionuclides concentration on plant materials from different areas in Sudan. 1993, M. Sc. Thesis, University of Khartoum, Sudan.

[9] Debertin, K. and R. Jianping, Measurement of the activity of radioactive samples in Marinelli beakers. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1989. **278**(2): p. 541-549.

[10] Sam, A.K., et al., Assessment of terrestrial gamma radiation in Sudan. Radiation protection dosimetry, 1997. **71**(2): p. 141-145.

[11] Leung, K., S. Lau, and C. Poon, Gamma radiation dose from radionuclides in Hong Kong soil. Journal of Environmental Radioactivity, 1990. **11**(3): p. 279-290.

[12] Kocher, D. and A. Sjoreen, Dose-rate conversion factors for external exposure to photon emitters in soil. Health Physics, 1985. **48**(2): p. 193-205.

Table captions

Table 1: The calculated annual dose, D.

Table 2: The calculated annual effective dose, H.

Table 3: The calculated equivalent activity, Ra_{eq}.

Table 4: The calculated index of the external radiation, H_{ex}.

Fig. 1 States of the Sudan.

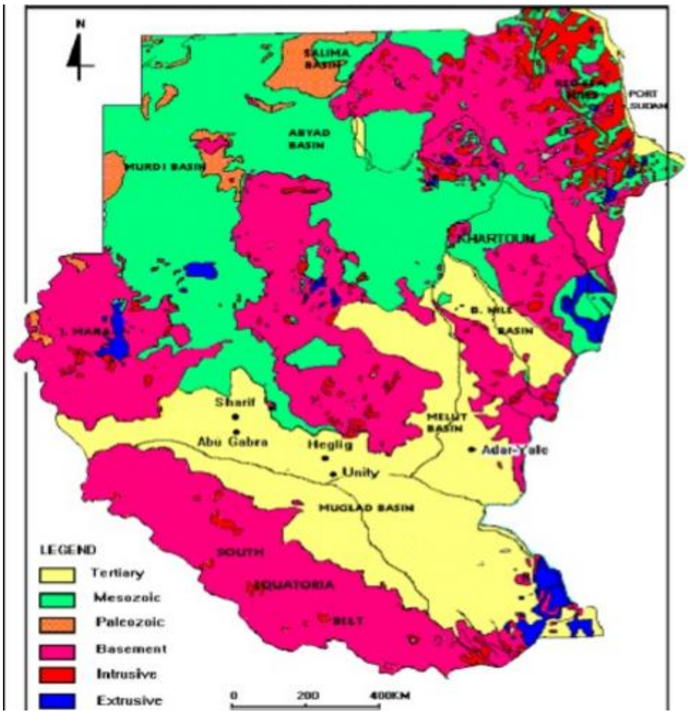

Fig. 2 Sudan Geological map.

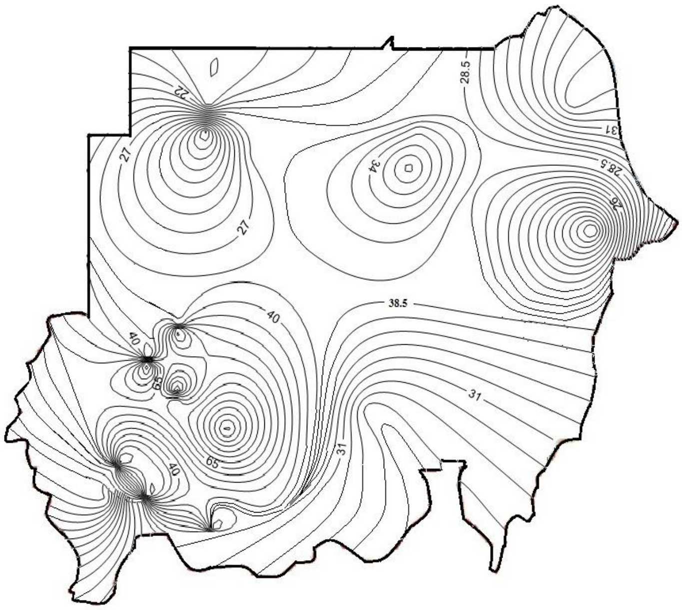

Fig. 3 The surface distribution of air absorbed dose, D, in Sudan.

Table 1: Dose Rate in air *D* (nGy/h).

North & Nahr El Nile	Darfor	South Kurdufan	North Kurdufan	Kartoum & Al-Gazira	Red Sea	Sinar & Gadarf & Blue Nile
25.2344	94.4946	37.2696	25.6966	29.399	25.2746	23.1842
36.3246	27.982	27.1732	44.9296	32.7136	31.1032	38.1642
19.246	103.3562	68.8116	99.1644	83.2134	79.9322	66.1614
20.5486	80.48	80.94	67.095	70.9292	86.1324	84.02
17.5042	25.667	22.88	25.374	35.794	21.1452	31.6698
32.473	22.0204	25.0634	18.7382	18.458	21.9772	31.065
33.0016	34.5462	27.7962	26.905	34.258	31.6776	28.8998
25.5172	29.045	35.6966	30.259	26.6436	25.2164	25.884
23.426	32.841	31.39	73.4448	59.757	26.9958	23.712
29.9186	21.502	34.339	24.9732	30.0268	27.583	24.173
22.0848	31.158	31.3384	27.9612	39.5072	38.4112	28.4242
19.7886	24.1452	55.6804	37.459	28.8662	40.7664	35.507

Table 2 : Annual Effective Dose *H* (μSv/y).

North & Nahr El Nile	Darfor	South Kurdufan	North Kurdufan	Kartoum & Al-Gazira	Red Sea	Sinar & Gadarf & Blue Nile
30947.47	44548.49	23603.29	25200.8	21467.15	39824.89	40473.16
31294.29	28729.65	36692.17	27084.8	24268.74	115888.2	45707.44
31514.31	36054.93	30996.77	28433.1	34317.12	33325.21	55101.66
40119.96	38144.96	46804.57	126756	84390.55	121615.2	102052.9
98028.85	81140.34	98700.67	99264.82	82285.31	86987.57	105632.8
103042.1	31478.01	28060.03	31118.67	43897.76	25932.47	38839.84
27005.82	30737.75	22980.53	22636.89	26952.84	38098.12	42367.46
34089.26	32996.29	42014.01	38849.41	35442.71	35620.79	43778.31
37109.64	32675.71	30925.39	31744.14	40276.2	38496.7	90072.7
73285.98	33107.65	29080.4	26370.05	42113.35	30627.13	36824.87
33827.79	29645.77	38212.17	38433.41	34291.62	48451.63	47107.5
34859.44	29611.67	68286.44	45939.72	35401.51	49995.91	43545.78

Table 3: The Equivalent Activity of the *Ra*.

North & Nahr El Nile	Darfor	South Kurdufan	North Kurdufan	Kartoum & Al-Gazira	Red Sea	Sinar & Gadarf & Blue Nile
9510.637	16975.17	7654.335	5388.322	927.578	4125.05	6258.402
3865.873	5640.89	13546.65	4352.893	5386.752	39949.63	3113.587
2647.072	988.03	530.017	3525.283	1668.095	5362.753	12943.1
2256.947	6209.143	7599.783	95514.88	97329.69	71987.26	111140.4
88730.93	87549.16	106380.3	101907.6	68825.1	77528.44	117710.6
59058.3	3763.82	2813.29	977.57	3456.45	1108.598	1114.523
3789.777	4143.677	3042.438	1760.09	937.438	4121.76	7834.578
5364.183	6070.96	8431.47	8888.367	7059.298	8675.345	7886.347
3129.17	2649.362	995.177	1776.67	14271.18	2832.3	65536.68

33614.54	3834.748	2531.25	1145.53	3783.26	1305.738	2199.633
3438.01	2532.25	4859.68	4337.342	3374.638	7129.903	11942.17
2913.913	942.298	1063.067	1802.25	1737.348	1030.637	1177.56

Table 4: The Index of the External Radiation H_{ex} .

North & Nahr El Nile	Darfor	South Kurdufan	North Kurdufan	Kartoum & Al-Gazira	Red Sea	Sinar & Gadarf & Blue Nile
0.138224	0.200594	0.103326	0.113573	0.10199	0.187585	0.188387
0.14559	0.13065	0.163944	0.124562	0.109326	0.537511	0.215117
0.146748	0.174993	0.150015	0.130383	0.162964	0.153906	0.253757
0.19112	0.173121	0.21681	0.581586	0.368043	0.56338	0.453549
0.435432	0.355985	0.439263	0.441788	0.364419	0.38613	0.467775
0.466083	0.145738	0.130235	0.146807	0.207752	0.122988	0.187645
0.124324	0.142233	0.105257	0.105702	0.128631	0.178705	0.195842
0.157767	0.15049	0.193317	0.177042	0.161628	0.161538	0.203386
0.174399	0.152925	0.14856	0.15049	0.180903	0.181586	0.408286
0.335284	0.153876	0.135878	0.124176	0.198248	0.145916	0.175646
0.157945	0.13858	0.179388	0.180725	0.160232	0.2267	0.215682
0.163677	0.141758	0.331957	0.219602	0.167835	0.244312	0.210662

Magdi Hassan Saad. "Natural Radiation Map of the Sudan ." IOSR Journal of Applied Physics (IOSR-JAP) 9.4 (2017): 35-39.