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RADIOLOGICAL STUDY OF ENVIRONMENTAL RADIONUCLIDES FOR SELECTED AREAS FROM NILE BANKS IN NORTHERN SUDAN

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ABSTRACT

Measurements of natural and some artificial radionuclides in sediments samples were performed. Twenty four samples have been collected along the River Nile in northern Sudan from Khartoum, Aljaily, Shandi, Adbra,Dongola,Wawa, Janas and Halfa using the standard sampling procedures. The technique was applied is gamma ray spectrometers with 8192 multichannel analyzer based on hyper pure germanium (HPGe) detectors N-Type with relative efficiencies 40% and resolution 1.95 keV (FWHM) at 1.33 MeV of Co–60 gamma line of a vertical configuration. The average activity concentrations of 226Ra (238U) series, 232Th series and 40K were 22.31, 25.24 and 372.98 Bq/kg (dry weight) respectively and the activity concentration of 137Cs is less than deduction limit (<DL) .The calculated average Absorbed Dose Rate in Air, average Effective dose rate in Air and average value for Radium Equivalent Activity were 41.29 nGy/h,0.20 mSv/y, 87.20 Bq/kg respectively. All results values were below the recommended international limits.

Keywords: *Radiological study, Natural radioactivity, River Nile sediments, , gamma ray spectrometer.*

I. INTRODUCTION

Study of natural radioactivity in Sediments is very important to determine the amount of change in natural background with time as a result of any radioactive decay because of their ability to trace contamination sources [1].Monitoring of any release of radioactivity to the environment will help for environmental protection. Sediments originate from soils and rocks and The River Nile drains materials of different source rocks (igneous, metamorphic and sedimentary) along its course from the central and eastern parts of Africa in the south to the Mediterranean Sea in the north (about 6285 km) [2].

The area of study is a part of the River Nile, start from Khartoum (capital of Sudan) to Halfa in northern Sudan about 909km [3,4,5]. .The present study aims to

- establishing a radiological baseline data by study the radioactivity concentrations of the natural and man-made radionuclides of the River Nile environment in northern Sudan help in drawing a radiological map .
- adjust a system for identification of real changes in the radioactivity levels so we can correlate this data with the occurrence of any accidental radioactive releases
- assess the environmental pollution effects on man.
- insure compliance with the world permissible standards for radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K in soil
-determine the potential risk by calculation of radiation doses (due to the daily Exposures from River Nile environment to man) from the theoretical modeling.

II. THEORETICAL BACKGROUND

Natural radiation sources are classified into Cosmic rays, Cosmogenic radionuclides which results from the interaction of cosmic rays products with the atmospheric gases, and Primordial radionuclides that include: 1- Series radionuclides (Uranium-Radium series, Actinium series, Thorium series) , 2- Non-series Primordial Radionuclides: They decay directly to a stable nuclide. The most important radionuclides are the isotopes of Potassium (40K).

Man-Made Radiation Sources include: Nuclear tests, Nuclear power plants, Sources used in different field.

Human exposure occurs by irradiation from sources outside the body (External exposure) and upon the decay of radionuclides taken into the body through ingestion and inhalation (Internal exposure) [6] . The exposure cased

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Deterministic Effects such as radiation sickness or burns after large doses ,and Stochastic Effects such as cataract formation , cancer and Genetic Effects[7].

III. EXPERIMENTAL SETUP AND SAMPLES PREPARATION

Twenty four sediments samples were collected by using Clamshell snappers along the River Nile branch in northern Sudan from Khartoum (the capital of Sudan) to Wadie Halfa (the last town before the River Nile enter Egypt) Which is very long distance(909 Km) so the samples were collected according to population percentage (Town and Big village) from Khartoum, Aljaily,Shandi,Adbra,Dongola,Wawa,Janas and Halfa, table (1) show the location of samples.

Table (1) Location of samples

NO	Town	Sample	Sample	Location	
1	Khartoum	S_{11}	S11	17^{O} 46\ 22\\ N	33^{O} 52\ 08\\ E
		S_{12}	S12	17^{O} 53\ 45\\ N	33^{O} 54\ 26\\ E
		S_{13}	S13	17^{O} 60\ 33\\ N	33^{O} 58\ 35\\ E
2	Aljaily	S_{21}	S21	19^{O} 11\ 26\\ N	30^{O} 27\ 66\\ E
		S_{22}	S22	19^{O} 14\ 35\\ N	30^{O} 28\ 12\\ E
		S_{23}	S23	19^{O} 16\ 12 \\ N	30^{O} 31\ 11\\ E
3	Shandy	S_{31}	S31	20^{O} 20\ 40\\ N	30^{O} 20\ 32\\ E
		S_{32}	S32	20^{O} 24\ 36\\ N	30^{O} 22\ 02\\ E
		S_{33}	S33	20^{O} 27\ 35\\ N	30^{O} 23\ 27\\ E
4	Atbara	S_{41}	S41	20^{O} 46\ 45\\ N	30^{O} 27\ 00\\ E
		S_{42}	S42	20^{O} 48\ 00\\ N	30^{O} 27\ 58\\ E
		S_{43}	S43	20^{O} 49\ 08\\ N	30^{O} 28\ 37\\ E
5	Dongola	S_{51}	S51	21^{O} 47\ 32\\ N	31^{O} 20\ 64\\ E
		S_{52}	S52	21^{O} 54\ 46\\ N	31^{O} 22\ 34\\ E
		S_{53}	S53	21^{O} 59\ 06\\ N	31^{O} 30\ 56\\ E
6	Wawa	S_{61}	S61	17^{O} 46\ 22\\ N	33^{O} 52\ 08\\ E
		S_{62}	S62	17^{O} 53\ 45\\ N	33^{O} 54\ 26\\ E
		S_{63}	S63	17^{O} 60\ 33\\ N	33^{O} 58\ 35\\ E
7	Janas	S_{71}	S71	19^{O} 11\ 26\\ N	30^{O} 27\ 66\\ E
		S_{72}	S72	19^{O} 14\ 35\\ N	30^{O} 28\ 12\\ E
		S_{73}	S73	19^{O} 16\ 12 \\ N	30^{O} 31\ 11\\ E
8	Halfa	S_{81}	S81	20^{O} 20\ 40\\ N	30^{O} 20\ 32\\ E
		S_{82}	S82	20^{O} 24\ 36\\ N	30^{O} 22\ 02\\ E
		S_{83}	S83	20^{O} 27\ 35\\ N	30^{O} 23\ 27\\ E

The collected Sediments samples were prepared for analysis according to the following procedure:

- The sample was separated from pepples and plant roots, weighed and dried for 10 hrs. in an oven at a temperature of 110oC, re-weighed until achieved constant weight to determine the water content.

- The sample was minced, homogenized and finally sieved through mesh sieve.

- The sieved samples were weighed and packed in Marinelli-type beakers (100 or 1000 ml capacity). Each sample was carefully sealed and stored for 4 weeks before counting (this time is about seven half lives of ^{222}Rn T1/2 = 3.823day) to reach secular equilibrium between^{226}Ra and its progeny [8] .

A gamma-ray spectrometry system (HPGe detectors N-Type with relative efficiencies 40% and resolution 1.95 keV (FWHM) at 1.33 MeV of Co–60 connected to spectroscopic amplifier system, A 8192 multichannel analyzer (MCA)

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with counting capacity of 228-1 counts per channel and computer which display the spectrums of acquisitioned and storage data) was used for the measurements to determine the concentration of radio-elements, potassium, uranium and thorium and the artificial radionuclide Cs-137. The detection of thorium and uranium depends on the assumption of secular equilibrium, where the rate of decay of the daughters becomes equal to the rate of decay of the parent [9].The gamma lines; 351.9 kev (pb-214), 609.3 kev (Bi-214),1120.3 kev (Bi-214) and 1674.5 kev(Bi-214) were used for determining Ra-226 (daughter of uranium-238).The gamma lines 338.34 kev (Ac-228),583.0 kev (Tl-208),911.1 kev (Ac-208) were used for determining Th-232 series., while K-40 was measured by its gamma line 1460.7 kev. The Energy calibration and efficiency calibration of the system was done using the standards Cs137, Co60, Eu152 and 226Ra point sources, its spectrum covers a wide energy range from 186 keV to 2.5 Mev [10]. The relative efficiency curve of the detector was made for 17 different energy values covering the energy range from 186 keV to 2450 keV. Each sample was put on the shielded detector and counted for an accumulating period of 36, 000 seconds (10 hours). Correction was made for background radiation level. The lower limits of detection (LLD) were determined from the background radiation. [11,12].

IV. RESULTS

The activity concentrations of ^{226}Ra of (^{238}U) series, ^{232}Th series , ^{40}K, and ^{137}Cs have been carried out for the collected sediments by using gamma spectrometry as shown in table (2) .

Table (2): The Gamma Activity of Radionuclides in Sediments samples

NO	Town	Sample	U-238series(Ra-226)	Th-232 series(Ra-222)	K-40	Cs-137
1	Khartoum	S_{11}	19.98±2.2	24.21±2.38	367.62±12.96	< DL
		S_{12}	12.89±2.35	21.39±2.62	338.20±14.37	< DL
		S_{13}	28.82±2.66	25.52±2.69	524.57±14.75	< DL
2	Aljaily	S_{21}	28.52±1.73	31.89±1.70	349.22±16.45	< DL
		S_{22}	28.52±1.10	31.89±2.59	371.94±13.83	< DL
		S_{23}	25.74±2.31	32.38±2.87	532.22±14.39	< DL
3	Shandy	S_{31}	18.58±0.92	20.09±1.65	332.26±11.93	< DL
		S_{32}	19.78±0.90	22.23±1.97	356.56±12.36	< DL
		S_{33}	19.78±0.3	20.51±1.7	356.56±12.36	< DL
4	Atbara	S_{41}	21.72±2.54	21.67±2.37	466.63±13.20	< DL
		S_{42}	16.06±1.81	20.05±1.68	312.87±13.69	< DL
		S_{43}	17.28±3.05	20.67±2.30	493.12±12.22	< DL
5	Dongola	S_{51}	21.96±2.06	24.89±1.81	366.07±12.94	< DL
		S_{52}	24.97±1.00	25.50±1.80	376.30±12.96	< DL
		S_{53}	23.50±0.98	24.06±1.75	375.50±12.16	< DL
6	Wawa	S_{61}	21.80±3.07	23.53±2.70	533.27±13.97	< DL
		S_{62}	21.56±1.91	24.54±2.38	508.49±12.92	< DL
		S_{63}	19.51±0.88	17.53±1.57	332.75±11.40	< DL
7	Janas	S_{71}	20.53±2.84	19.49±2.32	449.94±12.50	< DL
		S_{72}	21.54±2.01	19.92±1.98	490.55±11.31	< DL
		S_{73}	19.42±0.89	16.61±1.64	329.46±12.12	< DL
8	Halfa	S_{81}	23.08±2.32	29.39±2.61	182.35±9.07	< DL
		S_{82}	26.39±0.91	37.05±1.84	83.55±7.28	< DL
		S_{83}	33.46±0.90	50.74±1.90	121.56±7.61	< DL

- S : Sediments
- L D : Within the low limit of detection

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V. DISCUSSION

The average activity concentrations of ^{226}Ra (^{238}U) series is 22.31 Bq/kg and the average activity concentrations of ^{232}Th series is 25.24 Bq/k g, ranging from 12.89 Bq/kg in Sample S_{12} to 33.46 Bq/kg in Sample S_{83} for ^{226}Ra and from 16.61 Bq/kg in Sample S_{73} to 50.74 Bq/kg in Sample S_{83} for ^{232}Th. The average activity concentration of ^{40}K is 372.98 Bq/kg , ranging from 83.55 Bq/kg in Sample S_{82} to 533.27 Bq/kg in Sample S_{61} .The activity concentration of ^{137}Cs is less than deduction limit (<DL).

The small variations in the concentrations of the investigated radionuclides along the River Nile could be explained by the following points, with the help of the mechanical analysis for the sediment samples**:**

- The radioactivity content in sediments increases with the increase in the organic matter content, as it has a large cation exchange capacity, and decreases with the increase in total carbonate ions which are particularly effective in forming soluble complexes [13,14].

- There is a positive correlation between clay and silt percentage and the radioactivity concentration in sediments, and a negative correlation between sand percentage and the radioactivity concentration in sediments [15]. The clay minerals are composed mainly of plate-like particles of secondary aluminum silicates which have a negative charged surface and so, they have the ability to attract cations that can exchange with the cations adsorbed on the clay surface. This explains why most of the radionuclides in sediments and soils are adsorbed on clay and silt rather than on sand, because the specific activity of radionuclides decreases as the particle size increases [14,16].

- The variation in the activity concentration of ^{40}K content in sediments is attributed to the variation in clay and silt, sand and organic matter percentages along the river.

- The very low concentration of ^{137}Cs in sediments is mainly attributed to the global fall-out due to nuclear weapons testing and nuclear accident releases. This conclusion was based on the absence of the short-lived ^{134}Cs($t_{1/2}$= 2.06 years) [17, 18, 19].

- The ^{232}Th / ^{238}U ratio has a mean value of 1.13 The higher concentration of 232Th compared with that of 238U may be explained by the relatively greater geochemical mobility of 238U compared to 232Th [20].. Also the ^{232}Th content in sediments or soils increases more than other radionuclides with the increase in fine particles [21].

- The obtained results of the natural radionuclides are within the world typical ranges for ^{238}U (10-50) Bq/kg, ^{232}Th (7-50) Bq/kg and ^{40}K (100-700) Bq/kg dry weight respectively as reported in the UNSCEAR,1993 [22].

Dose Assessment : The exposure dose rate at one meter above the ground, The Effective dose rate and Radium Equivalent Activity(In order to compare the specific activities of samples containing different amounts of ^{226}Ra (^{238}U) series, ^{232}Th series and ^{40}K) from the natural radionuclides ^{226}Ra (^{238}U) series, ^{232}Th series and ^{40}K were calculated for the sediments samples using the formulas

$$D = R_k C_k + R_u C_u + R_{Th} C_{Th} \qquad (1)$$

Where:

D is the absorbed dose in nGy/hr.

R_k, R_u, R_{Th} are the conversion factors, expressed in nGy/hr.per Bq/kg.

C_k, C_u, C_{Th} are the concentration of ^{40}K, ^{238}U series and ^{232}Th series respectively, expressed in Bq/kg [23,24].

$$E = D . T . Q . Q_f \qquad (2)$$

Where:

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E= Effective dose rate (mSv y^{-1}) D= Dose rate (nGy h^{-1}) .

T=Time in hours =24 h .365.25 d Q= conversion coefficient= 0.7 Sv Gy^{-1} y^{-1}

Q_F= Occupancy factor=0.8 [24,25,26,27].

$$Ra_{eq} = C_{Ra} + 10 / 7\ C_{Th} + 10 / 130\ C_K \quad (3)$$

Where:

Ra_{eq}= Radium Equivalent Activity

C_{Ra} , C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, and this formula is based on the estimation that 1 Bq/kg of ^{226}Ra, 0.7 Bq/kg of ^{232}Th or 13.0 Bq/kg of ^{40}K produce the same gamma dose rate [28,29]. All the results are represented in table (3) .

Table (3) : The Absorbed dose rate , Effective dose rate, Radium Equivalent Activity from sediments samples

NO	Town	Sample	Absorbed dose rate nGy/h	Effective dose rate mSv y-1	Radium Equivalent Activity Bq/kg
1	Khartoum	S_{11}	39.38	0.19	82.91
		S_{12}	32.20	0.16	69.52
		S_{13}	52.54	0.26	105.70
2	Aljaily	S_{21}	47.52	0.23	101.01
		S_{22}	48.49	0.24	102.76
		S_{23}	53.76	0.26	113.02
3	Shandy	S_{31}	35.30	0.17	72.89
		S_{32}	37.91	0.19	79.03
		S_{33}	37.18	0.19	76.57
4	Atbara	S_{41}	43.70	0.21	88.64
		S_{42}	32.64	0.16	68.82
		S_{43}	41.47	0.20	84.81
5	Dongola	S_{51}	40.91	0.20	85.74
		S_{52}	43.60	0.21	90.42
		S_{53}	41.98	0.21	86.78
6	Wawa	S_{61}	39.76	0.20	96.51
		S_{62}	46.62	0.23	95.80
		S_{63}	34.72	0.17	70.20
7	Janas	S_{71}	41.26	0.20	83.05
		S_{72}	43.86	0.22	87.83
		S_{73}	34.65	0.17	68.54
8	Halfa	S_{81}	35.67	0.18	79.15
		S_{82}	36.88	0.18	85.80
		S_{83}	49.05	0.24	115.38

S: Sediments

The results obtained show that the estimated Absorbed dose rates from Sediments along the River Nile bank in northern Sudan are within the typical world range (24.0-160.0) nGy/h [30] and Effective dose rates from samples is less than world maximum value(1 mSv/y) [31] also the results is less than The maximum radium equivalent values (370.00)Bq/kg [32,24,25].

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VI. CONCLUSSION

The study show that the natural and artificial radioactivity levels of $^{226}Ra(^{238}U)$ series, ^{232}Th series , ^{40}K and ^{137}Cs for the selected samples from River Nile bank in northern Sudan are within the normal values of naturally occurring levels, and have been found to be in good agreement with the stander values sited in the literature .Also these data are considered as baseline data for drawing a radiological map of the River Nile in northern Sudan and as reference values that can be used in emergency radiation action.

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