Measurement of Natural Radioactivity Elements in Chromite Rocks in Blue Nile State South of Sudan.

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Abstract

This paper describes the results of a radiological survey for the purpose to determine the level Radioactivity concentration in chromite rocks for establishing a basic database of radioactive elements in rocks. Herein, we focus on analyzing radioactivity indices in thirty samples of Chromite rocks have been collected from different locations in Blue Nile State, twenty samples representative Gerri mountain area, and ten samples Gam mountain area respectively. As such, the data provide the basis for a reference map to detect emissions or a significant increase in radiation level in the region. Rocks radioactivity were measured by gamma ray spectrometer using an efficiency NaI (Tl) detector. The comparison between two locations is used by independent t-test. The activity concentrations of three natural radionuclides namely ^{226}Ra, ^{232}Th and ^{40}K has been determined. They results showed that these radionuclides were present in average activity concentration of (6.05±6.22, 6.27±6.7 and 50.97±74.47Bq/kg) respectively, these results were lower than the worldwide levels. The average absorbed dose rate (D_R) was 8.8±9.76 nGy.hr^{-1}, the average Annual Effective Dose equivalent (AEDE) was 0.01±0.01mSv. y^{-1}. The Radium Equivalent activity concentration (Ra_{eq}) was 19.12±20.8 Bq/kg. Hex 0.08±0.14 and Hin 0.16±0.04 for all rock samples of chromite of both area, these results were does not poses any risks, as evidenced by the values of the external hazard (Hex), absorbed dose rate D(nGy.hr^{-1}, radium equivalent (Raeq), and Annual Effective Dose Equivalent (AEDE) indices (all values were less than recommended levels for worldwide and some countries). However the concentration means of the ^{40}K, ^{226}Ra and ^{232}Th in Garri Mountain has highly significantly (P≤ 0.01) over that of the Gam Mountain.

Keywords: Chromite rocks, Uranium, Thorium, Potassium

1. Introduction

Natural sources of radiation are known to be the most significant means by which the public are exposed to radiation. These are mainly due to the primordial radionuclide, such as^{40}K and radionuclides from the ^{238}U and^{232}Th decay series. Uranium and thorium occur at trace levels in the earth crust, and 0.018% of the total amount is potassium is ^{40}K (Mujahid,*et al*., 2008).The radioactive due to natural radionuclides rocks generate a significant component of the background radiation exposure to the population. The terrestrial component of the natural background is dependent on the composition of the rock (Karahan and Bayulken, 2000).Radionuclides exist everywhere on earth-atmosphere, surface soil and subsurface rocks and radiation from these radionuclides mainly depends on geological and geophysical conditions, the radiation being higher in igneous (e.g. granite) and lower in sedimentary rocks with the exception of shale and phosphate rocks which in some cases may have relatively high content of radionuclides (Joshua, *et al*., 2008)

Many studies in this field are focusing on the measurements of radioactivity concentrations to determine the areas of high levels and correlation between radioactivity in soil and non-radioactivity in soil and geological structure of areas under study (Sahoo,*et al*, 2011; Rashed-Nizam,*et al.*, 2015; Iddris,*et al.*, 2016; Nkuba,*et al.*, 2017; Ribeiro,*et. al.*, 2018). In Sudan, there are some previous research conducted to study the radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K in various environmental compartments (Iddris,*et al*., 2013; Fadol, *et al.*, 2016; Iddris,*et al*., 2016; Abalhamid,*et al*., 2017), as a part of environmental radiation monitoring program. Radioactivity of rocks is usually caused by one of three natural sources of gamma-radiation: potassium, uranium and thorium. Each of those elements in natural conditions contains a fraction of radionuclide that can be detected in either direct or indirect way. The isotope ^{40}K emits gamma-rays with energy of 1.461 MeV, thus the determination of^{40}K is considered as direct. The concentration of ^{40}K is given in mass percentage. The determination of ^{238}U is based on the detection of the ^{214}Bi radionuclide, which is a member of the ^{238}U decay series emitting the energy of 1.76 MeV. In the case of ^{238}U, the detection is therefore indirect and the concentration is given in ppm eU (equivalent of uranium).

Brathwaitea, *et al*., (2017) found that podiform chromitites samples in the harzburgite zone show elevated Ir and Ru values, similar to the levels of enrichment of these platinum group elements (PGE) found in podiform chromite deposits in ophiolites worldwide. The PGE values in dunite-hosted chromitites from Baldy Ridge (Matakitaki) have elevated Pt, Pd and Rh, as is found in cumulate dunite zones in some other ophiolites.

Objectives: the main aims of this study are to evaluate the naturally occurring radioactive materials (NORM) from chromite rocks in Garri and Gam mountains and establish base-line data of the radiation levels in the areas.

2- Materials and methods

2.1The study area

The area under consideration (Figure 1) is located in the Blue Nile State mainly Jebel Gerri series mining area, about thirty two Kilometers East of El rosaries Dam, The area is bounded by the following coordinate latitudes 11.46 - 31.60 °N and 11.46 -51. 29 °N, longitudes 34.40-33. 47 °E and 34.41-13. 45 °E and along Jebel Ingessana series (Gam mining) area, about eighty Kilometers Southwest to Eldamazine. The area is bounded by the following coordinate latitudes 11.15 - ll.30 °N, longitudes 33.55 - 34°.The study area located within a transition climate zone between the humid/sub-humid southern Sudan regions.

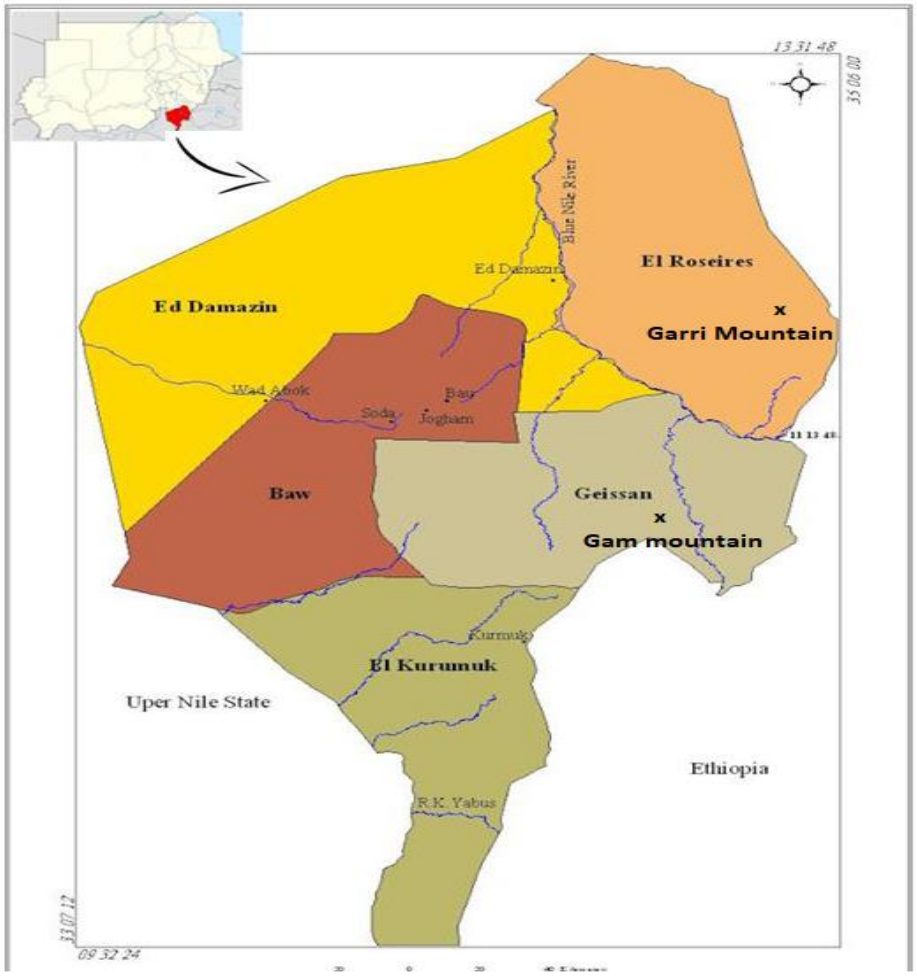

Figure 1 Map of the Blue Nile State showing the 30 sampling sites located at regular intervals as the samples were collected during field surveys of the areas.

2.2. Geology of the study area

The area lies in an area of known regional geology, and shows similarity with the geology of Ingessana, where massive consists of serpentinized hartzburgites and dunite with metadolerite, epidiorite and gabbros and with psammopelitic metamorphosed rocks and marbles around the hills. The mineralization associated with Ophiolitic belts include Podiform chromite, asbestos, talc and base metals (Cu, Ni and Co) mineralization. The study area shows a dominance of dunite rocks (more than90% olivine), which is usually (from the regional geology) found between pyroxenites and hartzburgites in a belt-shape. It forms a low-lying ground and expected to extend to a thickness of 2.0 Km. The dunite is massive, dark green in color but it exhibits a brown color on the weathered surface. Near the contact with hartzburgites the pyroxene crystals are aligned along the foliation planes which coincide with the general are direction. The dunite which contains vienlets of chromite is partially serpentinized thus it is relatively more fresh in comparison with the other rock formation. In some area, reaction of the dunite with the pegmatitic fluid progressively produced talc, asbestiform anthophyllite, and ferroan phlogopite (Sharma 1987). The chromite deposit associated with the Ultrabasic rocks of Garri Mountain, are important place of active, since the deposits are located in secured area to the east of Elroseires town reported by (Mohamed, Noor, and Khalid., 2012 and Figure 2.2).

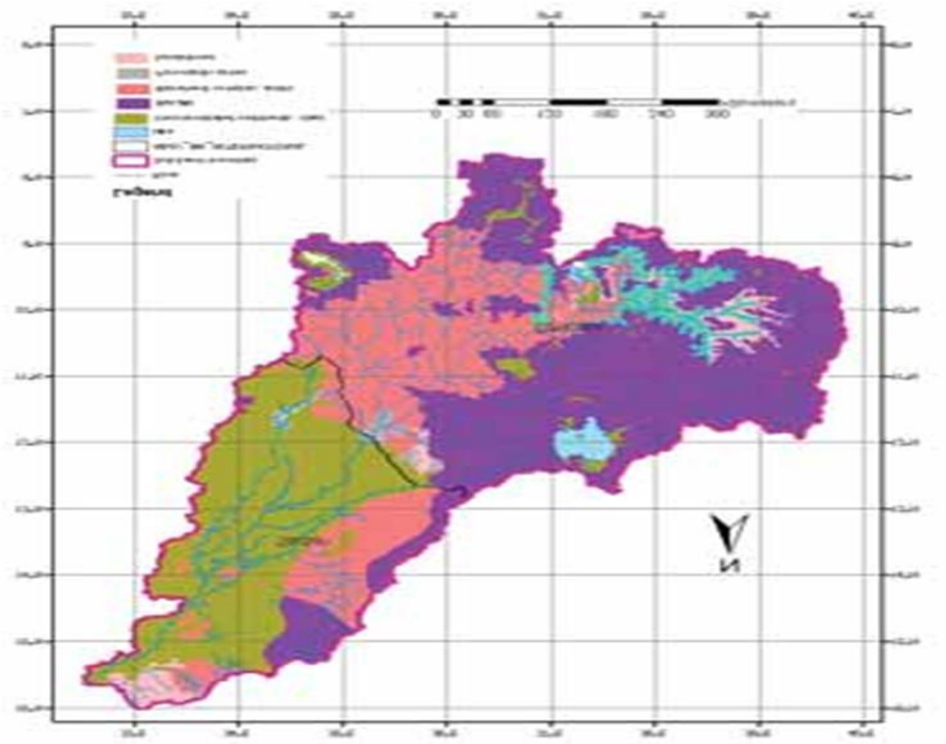

Figure 2 Geological map of the study area, as extracted from Sudan geological map (Babiker 2006).

2.3. Samples collecting and preparing

From Gerri mountain series and Ingessana Gam series thirty rock samples of chromite were collected in a fresh clean polyethylene bags and labels. The amount of sample was about 1 kg and then samples homogenized and sent to the laboratory where further preparation taken place then removal of weathering crust, washing with distilled water and drying at about 100°C, crushing with a mechanical jaw-crusher or manually with a steel hammer, an amount of crushed sample is pulverized in a Tema tungsten carbide disc mill and the powder was then kept in plastic containers for various analysis purposes.

2.4. Radioactivity measurements

Radioactivity measurements was performed using Gamma Spectrometer based on high efficiency NaI (Tl) detector The detector efficiency was calibrated using a mixed radionuclide sources (MW625) in 500 ml Marinelli beaker geometry. The container was placed directly on the detector and counted for overnight.

2.4.1. Calculation of radiological hazard indices

The radiation effects in the air can be expressed in terms of the exposure rate or the absorbed dose rate in air at 1 m height. In this study the absorbed dose rate D (nGy/h) in air at a height of 1 m above ground surface was calculated from the measured The mean activity concentrations of ^{226}Ra (^{238}U), ^{232}Th, and ^{40}K (Bq.kg^{-1}) in the rock samples are used to calculate the absorbed dose rate given by the following formula (Beck, H.L., 1972., Belivermis, *et al*., 2010).

$$D_R\ (nGy.h^{-1}) = 0.461\ A_U + 0.623\ A_{Th} + 0.0414\ A_K \qquad (1)$$

2.4.2. Annual effective dose (AEDE)

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

$$\text{AEDE}\ (\text{mSv.y}^{-1}) = \text{D}\left(\frac{\text{nGY}}{\text{h}} \times 24\text{hr} \times 365\ \text{d}\right) \times 0.7\frac{10^3\text{mSV}}{10^9\ \text{nGY}} \times 0.2 \qquad (2)$$

0.7 Sv/Gy is the conversion coefficient from absorbed dose in air to effective dose received by an individual, and 0.2 for the outdoor occupancy factor (UNSCEAR, 1993-2000).

2.4.3. Radium equivalent activity (Ra_{eq})

Due to a non uniform distribution of natural radionuclides in the soil samples, the actual activity level of ^{226}Ra, ^{232}Th and ^{40}K in the samples can be evaluated by means of a common radiological index named the radium equivalent activity (Ra_{eq}) (Beretka and Mathew. 1985). It is the most widely used index to assess the radiation hazards and can be calculated using Equation 2.5 given by (Beretka and Mathew. 1985). This estimates that 370 Bq.kg-1 of ^{226}Ra, 259 Bq.kg^{-1} of ^{232}Th and 4810 Bq.kg^{-1} of ^{40}K produce the same gamma-ray dose rate (Belivermis, et al., 2010)

$$Ra_{eq}(Bq.Kg^{-1}) = A_U + 1.43A_{Th} + 0.077A_K \qquad (3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentration of^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1}, respectively. The permissible maximum value of the radium equivalent activity is 370 Bq.kg^{-1} which corresponds to an effective dose of 1mSv for the general public

2.4.4. External and internal hazard indices

External and internal hazard indices are calculate from investigate samples. The prime objective of these indices is to limit the radiation dose to permissible dose equivalent limit of 1mSv/y (ICRP 60, 1990). The external hazard index (Hex) is given by model proposed by(Krieger 1981) as:

$$H_{ex} = \frac{A_U}{370Bq.Kg^{-1}} + \frac{A_{Th}}{259Bq.Kg^{-1}} \frac{A_K}{4810Bq.Kg^{-1}} \leq 1 \qquad (3)$$

H_{ex} must not exceed the limit of unity for the radiation hazard to be negligible (Al-Hamarneh and Awadallah, 2009; Kurnaz et. al., 2007). On the other hand, the internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived progeny and is given by the following formula proposed by (Beretka and Mathew, 1985) as:

$$H_{in} = \frac{A_U}{185Bq.Kg^{-1}} + \frac{A_{Th}}{259Bq.Kg^{-1}} \frac{A_K}{4810Bq.Kg^{-1}} \leq 1 \qquad (4)$$

The values of H_{in} must also be less than unity to have negligible hazardous effects of radon and its short-lived progeny to the respiratory organs (Al- Hamarneh and Awadallah, 2009).

2.5. Sample preparation and measurements:

500 g of powder sample were sealed in a 500 ml Marinelli beaker with plastic covers to prevent the escape of the Radon gas and stored four weeks so as to allow for in growths of gaseous ^{222}Ra (half-life, 3.8 days, in the ^{238}U decay series) and its short-lived decay products (^{2l4}pb&^{2l4}Bi) to reach equilibrium with the long-lived^{222}Ra precursor in the sample. ^{232}Th decay series to attain secular equilibrium with their long- lived parent radio nuclides products (^{2l2}pb&^{228}Ac)

Each sample was placed into NaI detector and measured overnight hours. The ^{232}Th concentration was determined from the average concentrations of ^{212}Pb (238 KeV) and ^{228}Ac (911Kev) in the samples, and that of ^{238}U was determined from the average concentrations of the ^{214}Pb (352 KeV) and ^{214}Bi (609 KeV) decay products. Whereas ^{40}K concentration was measured directly using its (1460 KeV) gamma-line.

$$A(Bq) = \frac{N(cps)}{\mathbf{I\gamma}.\boldsymbol{\eta}} \qquad (5)$$

Where:

$\boldsymbol{\eta}$ is the efficiency of the detector at specific energy.
N is the net area of the peak (count per second).
Iγ is gamma intensity.
A is activity of the element (which is required to find).

To determine concentration activity per mass (specific activity) can be divided activity obtained by mass of the sample and the unit that Becquerel per Kilogram (Bq/Kg).

3. Results and discussion

The results of the mean average value the activity concentrations of ^{226} Ra, ^{232}Th and ^{40}K in Garri Mountain area from which the rock samples of chromite ore were collected, have been presented in table 1 and illustrated in figure 1.The mean concentration for rock samples of chromite ore in the study area were, 2.34, 1.68 and 13.26 for the^{226}Ra, ^{232}Th and ^{40}K Bq/kg respectively. However, the results of the mean average value the activity concentrations of ^{226} Ra, ^{232}Th and ^{40}K in Gam Mountain area were collected, have been presented in table 2 and illustrated in figure 2.The results showed that the mean average value concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Ingessana (Gam mining) area from which the rock samples were collected were, 13.47, 15.45 and 126.4 respectively. These results were similar to some previous research conducted to study the radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K in various environmental compartments in Sudan (Iddris, *et al.*, 2013, Fadol. *et al.*, 2016, Idriss, *et al.*, 2016 and Abalhamid, *et al.*, 2017) as a part of environmental radiation monitoring program.

As for comparing between both Gam Mountain and Garri Mountain areas, the results indicated that the average concentrations of ^{226}Ra, ^{232}Th and ^{40}Krange of the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Garri area were lower than the range of the activity concentrations in Ingessana (Gam Mountain) area (table 3). Also the data in table 4 showed that the concentration means of the ^{40}K and ^{232}Th in Garri Mountain has highly significantly ($P \leq 0.01$) over that of the Gam Mountain. As for comparing the current study with the some countries the data indicated that the values of the activity concentration of ^{226}Ra (^{238}U), ^{232}Th, and ^{40}K in Bq/kg is lower than that for some countries (Table 5). However, as for radioactivity levels in all rock samples of chromite ore of both mountains area does not poses any risks, as evidenced by the values of the external hazard (Hex), absorbed dose rate D(nGy.hr^{-1}, radium equivalent (Raeq), and Annual Effective Dose Equivalent (AEDE) indices (all values were less than recommended levels).

The comparison between our study and other studies may be useful to understand the distribution of radioactivity in different continents and may support global baseline data from Sudan as one of large area African country. The range of activity concentration of ^{226}Ra in the study areas is slightly less than the values for other countries in different continents. If we take Algeria and Egypt (Africa) as examples, we will find that the average of ^{226}Ra is around 2-110 Bq/Kg (Algeria) and 6-120Bq/Kg (Egypt) and the mean is around 30 (Algeria) and 37 (Egypt) Bq/Kg. The same variance we will find in the average of the concentrations of ^{40}K and ^{232}Th, which is around 66-1150Bq/Kg with the mean 370 Bq/Kg (Algeria), 29-650 Bq/Kg with the mean 320 Bq/Kg (Egypt) for 40K and 2-140 Bq/Kg with the mean 25Bq/Kg (Algeria) and 2-96 Bq/Kg with the mean 18 Bq/kg (Egypt) for ^{232}Th. The results of the current study showed that the ranges of the activity concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K vary from 0.35 - 10.4 and 1.28 - 6.2, and 0.7 - 102.6 Bq.kg-1 with the mean concentrations of 6.05, 6.27 and 50.97 Bq.kg^{-1}, respectively. According to the UNSCEAR report (2000), the worldwide activity concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K were reported to be 17- 60, 11- 64 and 140 - 850 Bq.kg^{-1} with the mean concentrations of 35, 30 and 400 Bq.kg^{-1}, respectively. The findings of the current study of the activity concentrations of ^{226}Ra (^{238}U), ^{232}Th and^{40}K were lower than the range of the other countries and worldwide (table.5). The reasons

of variation in activity concentrations could be due to differences in the soil characteristic and geological properties from one location to another.

The results which obtained from Garri and Gam mountains indicated that the activity concentrations of, absorbed dose rates, annual effective dose. Radium equivalent activity and hazard indices are shown in(Table 6). The average absorbed dose rate (D_R) was 8.8±9.76 nGy.hr^{-1}, the average Annual Effective Dose equivalent (AEDE) was 0.01±0.01mSv. y^{-1}. The Radium Equivalent activity concentration (Ra_{eq}) was 19.12±20.8 Bq/kg. H_{ex} 0.08±0.14 and H_{in} 0.16±0.04 for all rock samples of chromite of both area, these results were does not poses any risks, as evidenced by the values of the absorbed dose rate D(nGy.hr^{-1} and Annual Effective Dose, Equivalent (AEDE), radium equivalent (Raeq), and external hazard (H_{ex}) indices that all values were less than recommended levels for worldwide (UNSCEAR, 2000).

However the concentration means of the ^{40}K, ^{226}Ra and ^{232}Th in Garri mountain has highly significantly (P≤ 0.01) over that of the Gam mountain (Table 7).

Table 1. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in GarriMountain chromite ore.

Sample Code	Location	^{40}K (Bq/kg)	^{226}Ra (Bq /kg)	^{232}Th (Bq/kg)
A01	Garri	5.90	ND	ND
A02	Garri	3.70	3.40	1.97
A03	Garri	8.00	2.31	3.50
A04	Garri	10.50	ND	1.95
A05	Garri	4.20	0.35	1.28
A06	Garri	ND	10.40	3.36
A07	Garri	102.60	ND	1.46
A08	Garri	102.40	ND	1.49
A09	Garri	ND	1.54	2.38
A10	Garri	ND	6.50	1.60
A11	Garri	3.70	ND	ND
A12	Garri	1.60	ND	ND
A13	Garri	3.90	ND	1.36
A14	Garri	0.70	ND	ND
A15	Garri	3.50	ND	1.96
A16	Garri	1.40	2.97	1.90
A17	Garri	6.30	1.10	1.45
A18	Garri	3.30	ND	ND
A19	Garri	ND	8.90	1.71
A20	Garri	3.50	9.30	6.20
Mean		**13.26**	**2.34**	**1.68**
Min		**0.70**	**0.35**	**1.28**
Max		**102.60**	**10.40**	**6.20**
Mean±SD		**13.26±30.65**	**2.34±3.53**	**1.68±1.48**

Where, SD= standard deviation, ND= not detect

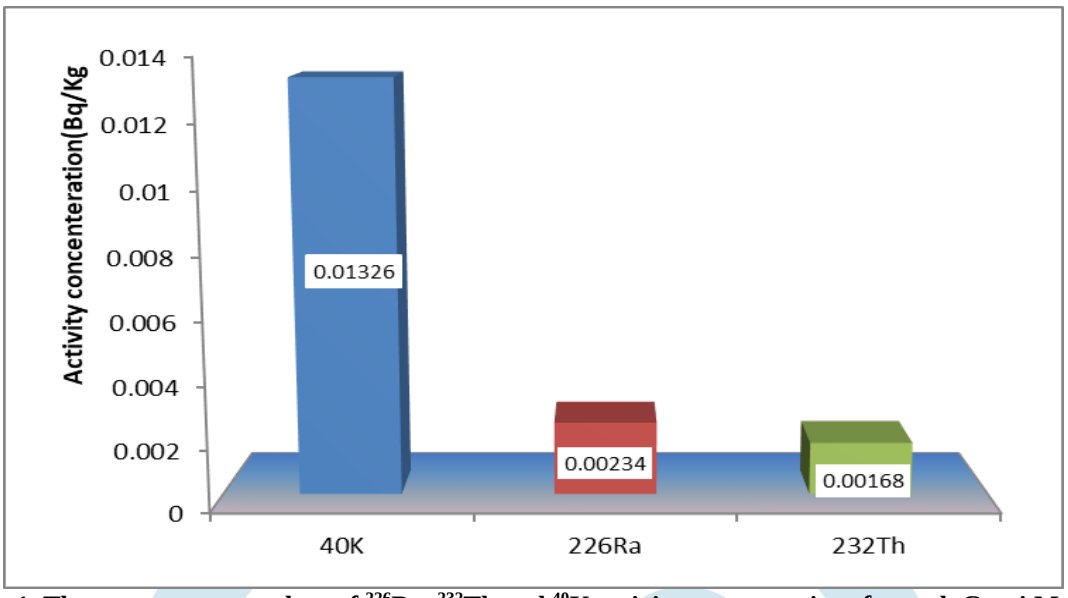

Figure 1. The mean average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations for each Garri Mountain measured in the current work.

Table 2. The results of the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Ingessana (Gam Mountain) area in Rock of chromite ore.

Sample Code	Location	^{40}K Bq/Kg	^{226}Ra Bq/Kg	^{232}Th Bq/Kg
B1	Gam	56.28	13.60	8.56
B2	Gam	184.00	14.50	25.60
B3	Gam	52.22	11.30	10.98
B4	Gam	174.00	10.90	19.40
B5	Gam	15.10	13.70	15.10
B6	Gam	54.14	14.50	10.80
B7	Gam	65.00	17.90	23.00
B8	Gam	242.00	15.70	21.20
B9	Gam	47.38	13.70	7.62
B10	Gam	238.00	8.90	12.20
Mean		**126.40**	**13.47**	**15.45**
Min		**47.38**	**8.90**	**7.62**
Max		**238.00**	**17.90**	**25.60**
SD		**79.73**	**2.88**	**6.67**
Mean ±SD		**126.4±79.73**	**13.47±2.88**	**15.45±6.67**

Where, SD= standard deviation, ND= not detect

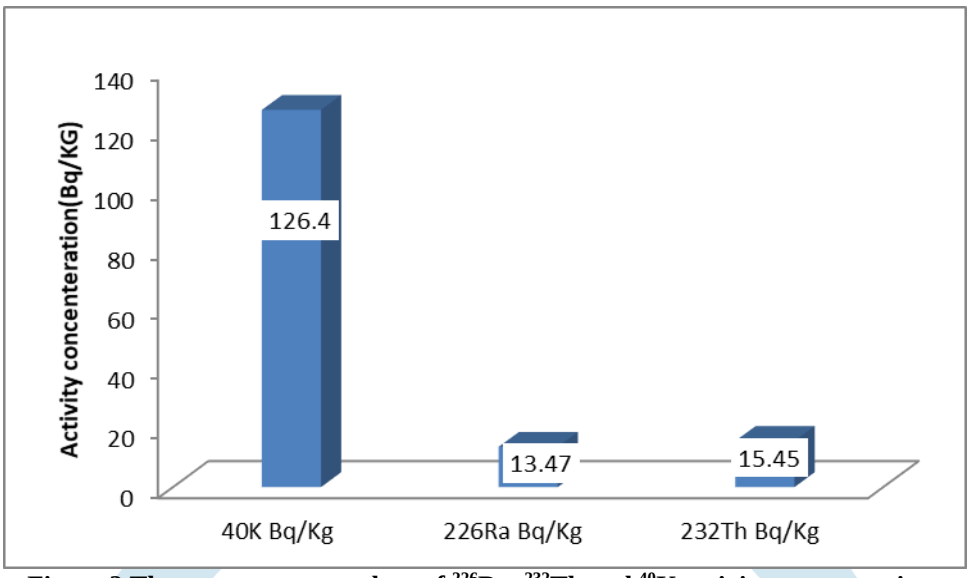

Figure 2.The mean average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations

Table3.Comparison between the average mean activity concentrations of ^{226}Ra,^{232}Th and^{40}K in Elgarri and Gam areas results with the mean value for the worldwide.

Sampling area	^{40}K Bq/Kg	^{226}Ra(^{238}U) Bq/Kg	^{232}Th Bq/Kg
Garri mountain	13.26	2.34	1.67
Gam mountain	126.40	13.47	15.45
Mean	50.97	6.05	6.27
Min	0.70	0.35	1.28
Max	102.60	10.40	25.60
Mean ±SD	50.98±74.47	6.05± 6.22	6.27±7.6
World Wide range	**140-850**	**17-60**	**11-64**
Mean	**400**	**35**	**30**

Table 4.Mean concentration of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg in both Garri and Gam areas

Location	N	Mean ±SD	F. value	P
^{40}K Bq/Kg concentration				
Garri	16	16.57 ± 33.6		
Gam	10	126.40 ± 80.10	22.6	**0.00****
^{226}Ra(238U) Bq/Kg concentration				
Garri	**14**	**3.34 ±3.90**		
Gam	**10**	**13.47 ±2.50**	**2.58**	**0.01***
^{232}Th Bq/Kg concentration				
Garri	15	**2.29 ±1.28**		
Gam	10	**15.45 ±6.40**	**36.4**	**0.00****

Where, N= number, SD = stander deviation. P= probability.

Table 5. Comparison of mean and range values of the activity concentration of ^{226}Ra (^{238}U), ^{232}Th, and ^{40}K in Bq.kg^{-1}with some countries

Country	^{238}U		^{232}Th		^{40}K		References
	Mean	Range	Mean	Range	Mean	Range	
Kuwait (north region)	**66.57**	**46-115**	**11-27**	**3.3-17**	**384.47**	**78-492**	**14**
Oman	**29.7**	--	**15-9**	--	**225**	--	**8**
Syria	**23**	**10-64**	**20**	**10-32**	**270**	**87-780**	**23**
Jordan	**49**	--	**27**	--	**291**	--	**3**
Iran	**28**	**8-55**	**22**	**5-42**	**640**	**250-980**	**23**
Egypt	**37**	**6-120**	**18**	**2-96**	**320**	**29-650**	**23**
Algeria	**30**	**2-110**	**25**	**2-140**	**370**	**66-1150**	**23**
India	**29**	**7-81**	**64**	**14-160**	**400**	**38-760**	**23**
Japan	**29**	**2.59**	**28**	**2-88**	**310**	**15-990**	**23**
US	**35**	**4-140**	**35**	**4-130**	**370**	**100-700**	**23**
Sudan	**15**	--	**33**	--	**230**	--	**17**

World-Wide value	**35**	**17-60**	**30**	**11-64**	**400**	**140-850**	**23**
Current study	**6.05**	**0.35-10.4**	**6.27**	**1.28-25.6**	**50.97**	**0.7-102.6**	

Table 6.The absorbed dose rate (D), the annual effective dose equivalent (AEDE), the radium equivalent activity (Raeq) and the external hazard index (Hex) in all rock samples of chromite ore.

Sampling area	**D(nGy.hr^{-1}**	**AEDE(mSv.y^{-1}**	**Raeq(Bq.Kg^{-1}**	**Hex**
Mean of Garri	2.672	0.003	6.032	0.053
Mean ofGam	21.061	0.028	45.290	0.122
Min	0.0289	0.0001	0.0539	0.0001
Max	30.46	0.04	65.28	0.18
Mean±SD	**8.8±9.76**	**0.01±0.01**	**19.12±20.8**	**0.08±0.14**
World-Wide range	**57**	**0.070**	**‹370**	**≤1**

Where, SD= standard deviation.

Table 7. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Elgarri and Gam areas in chromite ore.

	^{40}K Bq/kg	^{226}Ra /kg	^{232}Th Bq/kg
Gam mountain			
Mean	126.40	13.47	15.45
Min	47.38	8.90	7.62
Max	238	17.90	25.60
Mean ±SD	126.4±79.72	13.47±2.88	15.45±6.67
Garri mountain			
Mean	13.26	2.34	1.68
Min	0.70	0.35	1.28
Max	102.60	10.40	6.20
Mean ±SD	13.26±30.65	2.34±3.53	1.68±1.48

4. Conclusion

➢ The natural radiation levels of ^{40}K, ^{226}Ra and ^{232}Th were measured for thirty rock samples of chromite rocks using a gamma ray spectrum. The results clearly revealed a decrease the concentrations of radionuclide's across the study areas. Therefore, rocks of chromite in the study areas has no health effects on the population and does not poses any risk as evidenced by the values of the external hazard, absorbed dose rate and radium equivalent. . The occupational exposure of any worker shall be so controlled that an effective dose limits not exceeded 20 mSv per year averaged over five consecutive years. Therefore, the radioactivity found in the studied samples has very low values when compared with the dose limits of the world, recommended values, World Health Organization, (1996). This study is a reference for future studies.

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