

Study of Natural Radionuclides of some igneous rocks in Arabian Shield (South of Al- Madinah Al-Munawarah), Saudi Arabia

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Abstract: Igneous rocks are geologically important for their minerals and global chemistry information and for their economic content such as basalt, Andesite, and Diorite. ...etc. Western Saudi Arabia (the Arabian Shield) is covered with fields of lava known as Harrats. Al-Madinah is situated in a depositional basin surrounded by lava plateaus and hills and is bounded by Harrats which consists of igneous rocks. Six samples were collected from south of Al-Madinah and confined by the following co-ordinate Latitude N:23°44'59.9" to N:23°52'41.1" and Longitude E:39°43'14.8" to E:43°04'52.7". The dried samples were analyzed by XRD for the mineral constituents and the major concentrations for the samples are Augite, Albite, Biotite, Clinocllore, Pargasite, and Quartz. Also, the samples were analyzed by atomic absorption spectroscopy for the Al, Ca, K, Bi, Pb, and Th, concentrations in ppm and/or percent, values ranged from 7.13% to 8.79%, 1.21% to 6.92%, 0.54% to 4.24%, <10 ppm, 11.54 ppm to 77.06ppm, and <1 ppm to 5.58 ppm respectively. Gamma spectroscopy was applied to determine the concentrations of the radionuclides in the samples. There is disequilibrium between ^{238}U and ^{226}Ra , ^{234}Th was used to find the concentrations Bq/kg dry weight of the ^{238}U which ranged from 115.74 ± 0.08 to 309.05 ± 0.12 with mean value 216.30 ± 0.12 . While there is equilibrium between daughters (^{214}Pb and ^{214}Bi) of ^{226}Ra , so their activities concentrations Bq/kg dry weight were calculated for ^{226}Ra activities concentrations Bq/kg dry weight. The activity concentrations Bq/kg dry weight ranged from 29.77 ± 0.03 to 262.48 ± 0.06 , with mean value 106.47 ± 0.15 . Samples show high uranium than radium, and these represent the disequilibrium in the ^{238}U -series. The activity concentrations of ^{232}Th were calculated from its short half-life daughters ^{228}Ac and ^{208}Tl since there is secular radioactivity equilibrium in ^{232}Th series. The activity concentrations Bq/kg dry weight of the ^{232}Th ranged from 43.18 ± 0.08 to 299.75 ± 0.02 with mean value 110.35 ± 0.05 . The activity concentrations Bq/kg dry weight of the ^{235}U were 19.37 ± 0.04 for sample 1ba and 06.35 ± 0.09 for sample 2an and ND for the rest of samples. For ^{40}K , the activity concentrations Bq/kg dry weight of ranged from 532.69 ± 0.04 to 5371.48 ± 0.01 with mean value 2683.93 ± 0.09 . The average Ra_{eq} value was 470.93 Bq/kg which is higher than the internationally accepted value 370 Bq/kg and Annual Effective Dose (mSv/h) ranged from 0.08 to 0.59 with mean value 0.28. The results can be considered as base values for distribution of natural radionuclides in the region and reference information.

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1. Introduction

The rocks of the Arabian shield are mostly Neoproterozoic in age, but some date from the Archean and Paleoproterozoic, and a few intrusions yield Cambrian ages. Some areas in the east-central shield in Saudi Arabia contain Paleoproterozoic igneous rock, parts of a microplate indicated by an inherited continental isotopic signature that was largely destroyed by later intrusions (Saudi Geological Survey, 2012). The shield rocks result from the development and accretion of multiple volcanic arcs, separate sedimentary basins, and many different magmatic events, it is necessary to establish local stratigraphy to adequately account for these rocks and their relationships (Johnson and Kattan F. H, 2001).

The study of igneous rocks is important as products of deep earth processes such as melting of solid rock and crystallization of molten rock (magma), they provide researchers with important information regarding the mineralogical and chemical composition of the earth's interior. Also, some igneous rocks such as Granite and basalt have commercial and industrial use because of its high clay mineral content. In the manufacture of brick, granite is used for countertops and building facings. Basalt has been used in construction of buildings, pavers, and countertops as well. So, the radioactivity contents of various radionuclides in rocks may play an important role in health physics and geo- scientific research. These radionuclides pose exposure risks externally due to their gamma-ray

emissions and internally due to radon and its progenies, which emit alpha particles.

There are many studies about the concentrations of naturally-occurring radionuclides in igneous rocks from different regions of the world, these studies show that high levels of radiation are associated with igneous rock such as granite and basalt [Ahmed et al, 2006, El-Arabi, 2007]. Harb et al, 2008, „Awodugba et al, 2011, Raslan and El-Feky, 2012].

Western Saudi Arabia is covered not only with sand, but also with vast fields of lava which are known as *harraat*. Harraat in Saudi Arabia together form one of earth's largest alkali basalt regions, covering 180,000 square kilometers (Saudi Geological Survey, 2012). Al-Madinah is situated in a depositional basin surrounded by lava plateaus and hills within the western part of the Arabian Shield. Its ground surface elevations are around 600-610 m above sea level (Matsah and Hossain, 1993). Al-Madinah area is bounded by Harrats which consists of igneous rocks. Igneous rocks are geologically important for their minerals and chemistry information. Also, the radioactivity contents of radionuclides in rocks play an important role in health physics researchers (igneous granite and igneous basalt are used as building stones).

In this work, the main aim is to study some igneous rock samples collected from different locations at South of Al-Madina Al-Monwarehby X-RD spectroscopy to assign the mineral and chemical composition for each sample, atomic absorption spectroscopy was applied for some mineral concentrations in ppm and / or percent, and gamma spectroscopy to determine the concentrations of the radionuclides in the samples.

2. Experimental techniques

2.1. Sample preparation

Six samples were collected from south of Al-Madinah and confined by the following coordinate Latitude N:23°44'59.9" to N:23°52'41.1" and Longitude E:39°43'14.8" to E:43°04'52.7" as shown in figure 1. They contain the following: Basalt samples (1ba and 6ba) which is the most widespread of all igneous rocks, and comprises more than 90% of all volcanic rocks, it is used as aggregate, fill etc. in the construction and road industries, armour rock for seawalls, dimension stone, e.g. stone walls, curb stones, paving stones etc. Andesite samples (2an and 4an) is an extrusive rock intermediate in composition between rhyolite and basalt, it can be used as aggregate, fill etc. in the construction and road industries (often not ideal for concrete aggregate because of high silica content). Diorite sample (3di) is an intrusive rock intermediate in composition

between gabbro and granite. It is produced in volcanic arcs, and in mountain building where it can occur in large volumes as batholiths in the roots of mountains, it can be used as aggregate, fill etc. in the construction and road industries (often not ideal for concrete aggregate because of high silica content) and cut and polished for dimension stone for building facings, foyers etc. Microgranodiorite sample (5mi) is an intrusive rock, intermediate in composition between diorite and granite. Although often similar in appearance to diorite or granite, it has high quartz content. It is commonly produced in volcanic arcs, and in mountain building where it emplaces as large batholiths in mountain roots. Microgranodiorite is can be used as aggregate, fill etc. in the construction and road industries (often not ideal for concrete aggregate because of high silica content) and cut and polished for dimension stone for building facings, foyers etc. (Saudi Geological Survey, 2012).



Fig. 1 Map of the samples locations

Samples were grounded, sieved by 1mm x 1mm, then dried to 95°C for 24 hours in order not to lose the volatile polonium or cesium. The dried fine grained samples were packed in polyethylene Marinelli beakers for gamma spectroscopy, and then stored for up to four months to reach secular equilibrium between ^{238}U and ^{232}Th and their progenies.

Measurements

Ten grams of the dried samples were analyzed by XRD model Burker XR-D D8 Advance for the mineral constituents, also 10 grams of the dried samples were analyzed by atomic absorption model A Analyst 700 for the Al, Ca, K, Bi, Pb, Th, concentrations in ppm and/or percent. Samples were analyzed for concentrations of ^{238}U , ^{232}Th series, ^{235}U , and ^{40}K using the gamma spectrometer based on

Canberra hyper pure germanium detector "HPGe" coaxial detector with relative efficiency of 20% and FWHM 4.2 keV at 1461 keV, the measurements were done for a time period of twenty four hours.

For ^{238}U , a gamma-ray line of energy 63.29keV, of ^{234}Th , was used to find the concentrations. Gamma-ray lines of energies 295.09, 351.87, 609.31, 1120.27, and 1764.49 keV resulting from the decay of daughters ^{214}Pb and ^{214}Bi radionuclides (which they are in secular radioactivity equilibrium) were used to determine the activity concentrations of ^{226}Ra . The gamma-ray lines at 338.42, 911.07, 968.97, 583.10, and 2614.48 keV from the decay of short half – life daughters ^{228}Ac and ^{208}Tl were used to determine the activity concentrations of ^{232}Th respectively (since there is secular radioactivity equilibrium in ^{232}Th series); while the 143.8 and 1460.80 transitions were used to determine the activity concentrations of ^{235}U and ^{40}K respectively.

After analyzing the spectrum, the net counting rates for each detected photo peak were used to calculate the specific activity (A) in Bq/Kg for each detected nuclide using the following equation:(Amrani & Tahtat M., 2001).

$$A = \frac{C}{M \beta \epsilon} \quad (1)$$

Where: c is the net counting rate of a specific gamma ray (count per second)

M is the mass of the samples (kg)

β is the transition probability of gamma-decay

ϵ is the detector efficiency at the specific gamma-ray energy.

Distribution of ^{226}Ra , ^{232}Th and ^{40}K in environment is not uniform, so that the radioactivity has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq/kg to compare the specific activity of materials containing different amounts of ^{226}Ra , ^{232}Th and ^{40}K . Equation (2) was used to determine Ra_{eq} (Bq/kg) (Tufail *et al.*, 2006):

$$Ra_{eq}(\text{Bq}.kg) = C_{Ra} + (C_{Th} \times 1.43) + (C_K \times 0.077) \quad (2)$$

Where: C_{Ra} , C_{Th} and C_K are the concentrations Bq/kg for radium, thorium and potassium respectively.

Besides the radium equivalent activity, the total air absorbed dose rate D (nGy/ h) in the outdoor air at 1 m above the ground due to the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K (Bq/ kg) dry weight was calculated using the equation (3) (UNSCEAR 2000; Veigaet *al.*, 2006)

$$D(\text{nGy}/\text{h}) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_K \quad (3)$$

Where: C_{Ra} , C_{Th} , and C_K are the specific activities (concentrations) of ^{226}Ra , ^{232}Th and ^{40}K in Bq /kg respectively.

By using a conversion factor of 0.7 SvG/y and outdoor occupancy factor of 0.2 (people spend about 20% of their life outdoor) the Annual Effective Dose (in mSv/y) received by population can be calculated using equation:

$$D_{\text{eff}}(\text{mSv}/\text{y}) = D(\text{nGy}/\text{h}) \times 8,766 \text{ h} \times 0.7(\text{SvG}/\text{y}) \times 0.2 \times 10^{-6} \quad (4)$$

Where: D (nGy/h) is the total air absorbed dose rate in the outdoor.

8,766 h is the number of hours in 1 year.

10⁻⁶ is conversion factor of nano and milli.

3. Results and Discussions

3.1 Results of XRD spectrometer and Atomic Absorption spectrometer:

From the obtained results of XRD spectrometer and Atomic Absorption spectrometer represented in tables (1&2), it can be seen that, sample 1ba major constituent is AUGITE, it has the lowest concentration values in Al (7.13%) of all samples, while the concentrations of Ca (6.92%) and for Th (5.58 ppm=22.88 Bq/kg) are the highest values of all samples. The concentrations ranged from 4.08%, <10 ppm, and 19.77ppm for K, Bi, and Pb respectively. Sample 2an major constituents are ALBITE and BIOTITE. Concentrations of Al, Ca,, K, Bi, Pb and Th ranged from 7.38, 4.11, 2.22 in %, and <10, 17.54, and <1 in ppm respectively. Sample 3di major constituents are ALBITE, CLINOCHLORE, PARGASITE, QUARTZ. This sample has the highest values of concentrations in Al (8.79%) and Pb (77.06) ppm of all samples, concentrations of Ca, , K, Bi, and Th ranged from 4.26 and 2.12 in % and <10 and <1 in ppm respectively. Sample 4an major constituents are ALBITE, CLINOCHLORE, and, PARGASITE. The Concentrations of K(0.54%) and Pb (11.54 ppm) are the lowest values of all samples. The Concentrations of Al, Ca, Bi, and Th ranged from 8.67, 4.83 in %, <10, <1ppm respectively. Sample 5mi major constituents are ALBITE, CLINOCHLORE, and, PARGASITE. The Concentrations of Al, Ca, K, Bi, Pb and Th ranged from 8.39, 5.45, 1.33 in% and <10, 38.17, and <1 in ppm respectively. Sample 6ba major constituents are ALBITE, QUARTZ. This sample has the highest values of concentrations in K (4.24%) of all samples. The Concentrations of Al, Ca, Bi, Pb, and Th ranged from 7.26, 1.21 in % and <10, 44.32inppm, and (4.06 ppm-16.65Bq/kg) respectively, with additional minor and trace concentrations.

Table (1): The mineral constituents of six samples of igneous rocks analyzed by XRD spectrometer, (Leet et al., 1982, and Mineral Data, 2012).

Sam. code	Major	Minor	Trace
1ba	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆	ALBITE(NaCaAlSi ₃ O ₈), BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂), JUSITE(CaNaK) ₅ (SiAl) ₆ O ₁₅ H ₂ O, MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , QUARTZ(SiO ₂)	ANKERITECaFe ²⁺ _{0.6} Mg _{0.3} Mn ²⁺ _{0.1} (CO ₃) ₂ , CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , DOLOMITE(CaMg(CO ₃) ₂), NONTRONITENa ₃ Fe ³⁺ ₂ Si ₃ AlO ₁₀ (OH) ₂ 4(H ₂ O), OFFRETITEK ₂ ,Ca,Mg) ₂ .5Al ₅ Si ₁₃ O ₃₆ •15(H ₂ O), PARTHEITECa ₂ Al ₄ Si ₄ O ₁₅ (OH) ₂ •4(H ₂ O)
2an	ALBITE(NaCaAlSi ₃ O ₈), BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂),	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), MICROCLINE(KAISi ₃ O ₈), QUARTZ(SiO ₂)	CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , DOLOMITE(CaMg(CO ₃) ₂), HOHMANNITEFe ³⁺ ₂ (SO ₄) ₂ (OH) ₂ •7(H ₂ O), MONTMORILLONITE Na ₂ Ca ₁ Al ₂ Si ₄ O ₁₀ (OH) ₂ (H ₂ O) ₁₀ , PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , RAMSBECKITECu,Zn) ₁₅ (SO ₄) ₄ (OH) ₂₂ •6(H ₂ O)
3di	ALBITE(NaCaAlSi ₃ O ₈), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ , QUARTZ(SiO ₂)	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂), MICROCLINE(KAISi ₃ O ₈),	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ CALCITE(CaCO ₃), HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), MONTMORILLONITE Na ₂ Ca ₁ Al ₂ Si ₄ O ₁₀ (OH) ₂ (H ₂ O) ₁₀ , NONTRONITE Na ₃ Fe ³⁺ ₂ Si ₃ AlO ₁₀ (OH) ₂ 4(H ₂ O),
4an	ALBITE(NaCaAlSi ₃ O ₈), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ .	AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ MICROCLINE(KAISi ₃ O ₈), QUARTZ(SiO ₂),	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂), CALCITE(CaCO ₃), HALITE(NaCl), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄), PROBERTITENaCaB ₅ O ₇ (OH) ₄ •3(H ₂ O), SLAVIKITE NaMg ₂ Fe ³⁺ ₅ (SO ₄) ₇ (OH) ₆ •33(H ₂ O)
5mi	ALBITE(NaCaAlSi ₃ O ₈), CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ .	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂), QUARTZ(SiO ₂)	ALLOPHANE (Al ₂ O ₃)(SiO ₂) _{11.3} •2.5(H ₂ O), AUGITE(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆ CALCITE(CaCO ₃), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄) NONTRONITENa ₃ Fe ³⁺ ₂ Si ₃ AlO ₁₀ (OH) ₂ 4(H ₂ O), SAPONITE (CaNa)3(Mg,Fe ⁺⁺) ₃ (Si,Al) ₄ O ₁₀ (OH) ₂ 4(H ₂ O),
6ba	ALBITE(NaCaAlSi ₃ O ₈), QUARTZ(SiO ₂)	CLINOCHLORE(MgFe ²⁺) ₅ Si ₃ Al ₂ O ₁₀ (OH) ₈ , MICROCLINE(KAISi ₃ O ₈)	BIOTITE(K(MgFe ²⁺) ₃ AlSi ₃ O ₁₀ (OH)F ₂), CALCITE(CaCO ₃), GMELINITE(Na ₂ Ca)Al ₂ Si ₄ O ₁₂ •6(H ₂ O), GYPSUMCa(SO ₄)•2(H ₂ O), MAGNETITE(Fe ³⁺ ₂ Fe ²⁺ O ₄) MONTMORILLONITE Na ₂ Ca ₁ Al ₂ Si ₄ O ₁₀ (OH) ₂ (H ₂ O) ₁₀ , PARGASITE NaCa ₂ Mg ₃ Fe ²⁺ Si ₆ Al ₃ O ₂₂ (OH) ₂ ,

Table(2): Concentrations of Al, Ca, K, Bi, Pb and Th, for igneous rocks samples measured by Atomic Absorption Analyzer.

Samp. code	Elements	Al	Ca	K	Bi	Pb	Th	
	D L	0.05	0.05	0.05	10.00	7.50	1.00	4.10
	Units	%	%	%	ppm	ppm	ppm	Bq/kg
1ba		7.13	6.92	4.08	<10	19.77	5.58	22.88
2an		7.38	4.11	2.22	<10	17.54	<1	<4.10
3di		8.79	4.26	2.12	<10	77.06	<1	<4.10
4an		8.67	4.83	0.54	<10	11.54	<1	<4.10
5mi		8.39	5.45	1.33	<10	38.17	<1	<4.10
6ba		7.26	1.21	4.24	<10	44.32	4.06	16.65

3.2. Concentrations of ²³⁸U—²²⁶Ra series:

Rocks samples were measured using the gamma spectrometer. The results in table (3) show that, there is disequilibrium between ²³⁸U and ²²⁶Ra, a 63.29KeV photopeak, which comes the decay of ²³⁴Th, was used to find the concentrations. The activity concentrations Bq/kg dry weight of the ²³⁸U ranged from 115.74±0.08 to 309.05±0.12 with mean value 216.30±0.12. While there is equilibrium

between the daughters ²¹⁴Pb and ²¹⁴Bi of ²²⁶Ra, the activities of ²¹⁴Pb and ²¹⁴Bi were used to calculate the concentrations for ²²⁶Ra. The activity concentrations Bq/kg dry weight ranged from 29.77±0.03 to 262.48±0.06, with mean value 106.47±0.15. Samples show high uranium than radium, and these represent the disequilibrium in the ²³⁸U-series.

3.3. Concentrations of ^{232}Th :

The decay of short half-life daughters ^{228}Ac and ^{208}Tl were used to determine the activity concentrations of ^{232}Th since there is secular radioactivity equilibrium in ^{232}Th series. The activity concentrations Bq/kg dry weight of the ^{232}Th ranged from 43.18 ± 0.08 to 299.75 ± 0.02 with mean value 110.35 ± 0.05 . Comparing the concentrations values Bq/kg dry weight of ^{232}Th for samples 1ba and 6ba measured by Atomic Absorption Analyzer (22.88 and 16.65) with the concentrations values Bq/kg dry weight of ^{232}Th measured by the gamma spectrometer (299.75 ± 0.02 and 87.44 ± 0.04), which were calculated from the decay of short half-life daughters ^{228}Ac and

^{208}Tl). It turned out to be not consistent which showed that there is disequilibrium between ^{232}Th and its series.

3.4. Concentrations of ^{235}U

The activity concentrations Bq/kg dry weight of the ^{235}U were 19.37 ± 0.04 for sample 1ba and 06.35 ± 0.09 for sample 2an and ND for the rest of the samples.

3.5. Concentrations of ^{40}K

The activity concentrations Bq/kg dry weight of the ^{40}K ranged from 532.69 ± 0.04 to 5371.48 ± 0.01 with mean value 2683.93 ± 0.09 .

Table (3): The activities concentrations Bq/kg dry weight of the ^{238}U , ^{226}Ra , ^{232}Th , ^{235}U and ^{40}K for igneous rocks samples.

Samp. code	Lat. and Long.	^{238}U	^{226}Ra	^{232}Th	^{235}U	^{40}K
1ba	N: $23^{\circ}44'59.9''$ E: $39^{\circ}43'14.8''$	307.82 ± 0.16	262.48 ± 0.06	299.75 ± 0.02	19.37 ± 0.04	4282.19 ± 0.02
2an	N: $22^{\circ}37'33.5''$ E: $41^{\circ}17'53.1''$	115.74 ± 0.08	95.13 ± 0.40	87.13 ± 0.05	06.35 ± 0.09	2325.36 ± 0.12
3di	N: $23^{\circ}32'45.6''$ E: $43^{\circ}00'56.9''$	205.63 ± 0.18	82.32 ± 0.37	100.18 ± 0.06	ND	2195.99 ± 0.03
4an	N: $23^{\circ}52'41.1''$ E: $43^{\circ}04'52.7''$	176.07 ± 0.17	29.77 ± 0.03	43.18 ± 0.08	ND	532.69 ± 0.04
5mi	N: $23^{\circ}32'28.1''$ E: $43^{\circ}02'26.5''$	183.46 ± 0.20	43.47 ± 0.02	44.42 ± 0.04	ND	1395.87 ± 0.31
6ba	N: $23^{\circ}46'37.0''$ E: $42^{\circ}17'40.7''$	309.05 ± 0.12	125.62 ± 0.03	87.44 ± 0.04	ND	5371.48 ± 0.01
Min.		115.74 ± 0.08	29.77 ± 0.03	43.18 ± 0.08	06.35 ± 0.09	532.69 ± 0.04
Max.		309.05 ± 0.12	262.48 ± 0.06	299.75 ± 0.02	19.37 ± 0.04	5371.48 ± 0.01
Mean		216.30 ± 0.12	106.47 ± 0.15	110.35 ± 0.05	12.86 ± 0.07	2683.93 ± 0.09

3.6. The Ra_{Eq} (Bq/kg), D (nGy/h), and D_{eff} (mSv/y)

The radium equivalent activities of samples under investigation were calculated and were shown in table 4. The average Ra_{eq} value for the studied area was 470.93 Bq/kg which is higher than the internationally accepted value 370 Bq/kg (UNSCEAR, 2000). The highest value of

Ra_{eq} is in sample 1ba and the lowest one is in 4an. Annual Effective Dose (mSv/y) ranged from 0.08 to 0.59 with mean value 0.28 . These calculated values were lower than the estimated world-averaged values (< 1 for D_{eff} (mSv/y)).

Table (4): The Ra_{Eq} (Bq/kg), D (nGy/h), and D_{eff} (mSv/y) for igneous rocks samples.

Samp. No.	Ra_{Eq} (Bq/kg)	D (nGy/h)	D_{eff} (mSv/y)
1ba	1020.85	477.89	0.59
2an	398.78	191.92	0.24
3di	394.67	188.58	0.23
4an	132.54	061.68	0.08
5mi	214.47	104.14	0.13
6ba	664.26	331.08	0.41
Min.	132.54	061.68	0.08
Max.	1020.85	477.89	0.59
Mean	470.93	225.88	0.28

4. Conclusion

The obtained results of XRD spectrometer show that the major concentrations for the samples are AUGITE, ALBITE, BIOTITE, CLINOCHLORE, PARGASITE, and QUARTZ. The concentrations values of Al, Ca, K in %, Bi, Pb, and Th in ppm, for igneous rocks samples were measured by Atomic Absorption Analyzer, ranged from 7.13% to 8.79%, 1.21% to 6.92%, 0.54% to 4.24%, <10 ppm, 11.54 ppm to 77.06ppm, and <1 ppm to 5.58 ppm respectively. The ^{238}U activity concentrations of the samples are higher than those of ^{226}Ra and ^{232}Th . ^{40}K was found to vary with variation of rock types, it has high concentrations. The radionuclides activity concentrations values of ^{238}U , ^{226}Ra , and ^{40}K are the highest for the samples 1ba and 6ba. The radium equivalent activity was calculated from the concentration of the natural radionuclide where the activity range 132.54 to 1020.85 Bq/kg with mean value 470.93 Bq/kg, which is higher than the internationally accepted value 370 Bq/kg. The mean values of the annual effective dose (D_{eff} (mSv/y) was found to be less than one (0.28), This calculated value was within the worldwide mean values (≤ 1 for D_{eff} (mSv/y) (UNSCEAR, 2000). Gamma-ray results can be considered as a base line monitoring for natural background radioactivity levels.

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