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Natural Radioactivity of Building Rocks in quarries South-west part of Yemen.

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Abstract: *Totally of 40 samples of 6 different building materials rocks were collected from 11 quarries which are founding in south-west part of Yemen. all samples from quarry Basalt , Tuff ,Granite , SchistGranit , Migmatit and Limestone which are known as shown in table,3.1. Measurement were done by High Purity Germanium(HPGe) to determine the concentration natural radionuclide of (C_{Th} , C_{Ra} and C_k). Activity Concentration Index(I) , Radium Equivalent(Ra_{eq}) , Dose rate (D) , Annual effective doses Equivalent(AEDE) ,External hazards index(H_{ex}) , Internal hazards index(H_{in}) were calculated to Building Rocks.*
The results of Activity concentration(I) for samples were determined k_{40}(50.68 – 1963.60)Bq/kg .Ra-226 (MDA – 300.30)Bq/kg . Th-232 (MDA - 170.933)Bq/kg. the average values for radium equivalent are 264.04 Bq/Kg. it is less than the safe limits as recommended by the (OECD). The mean measured absorbed dose rates in all location was 121.653 nGy.h^{-1} . the average value for indoor effective dose 0.619 mSvy^{-1} and the average annual effective dose equivalent for outdoor value 0.155 mSvy^{-1} and do not exceed the limits defined inEU. The External hazards index (H_{ex}) with an average 0.71 for (Hex) which is below than unity.the average values of Internal hazards index(H_{in}) are 0.95 .it is below the internationality accepted value. The average for representative level index values were 1.96 mSv/y which are higher than 1 mSv/y.
The results of the present work indicate that a lot of quarries in Yemen with a normal level of natural radiation background, and the rocks from the studied area do not pose a significant radiological threat to population when used as construction materials except the quarries Megmatite and Schist-Gneiss.
***Key Words** : Activity Concentration Index(I) , Annual effective doses Equivalent(AEDE) , building materials , concentration natural radionuclide of (C_{Th} , C_{Ra} and C_k) , Dose rate (D) , External hazards index(Hex) , High Purity Germanium(HPGe) , Radium Equivalent(Ra_{eq}) ,*

1 Introduction

The building materials and industrial rocks which are principles important in development in any country and represent sub sector after oil in some country and resources depletion. There are extensively used along Yemen for this types of rocks and it exploit by traditional way therefore, the waste due to process quarrying are big amount and it needs to proceedings mitigation safe uses in construction dwelling the according to resulting . There are about more than 200 of quarries are produced building rocks using in construction dwelling and it working by random way.

Building rocks contain a natural radioactivity and emit gamma radiation influence by human body due to exposure to its radiation. According to United Nation Scientific Committee on effects of Atomic Radiation (UNSCEAR) report, that The natural radiation present the largest contributor source(87%) to external dose of world population. In this work we have been investigated about building rocks and health radiological effects to radiation in Yemen and to estimate the Radium- Equivalent activity , which is related to external exposure to ɣ-dose rate.

The result of concentration activity , radium-Equivalent , Dose rate were , Hazard index, and representative level index were compared with world average level index.

2 Definitions and Abbreviation

2.1 UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation.
2.2 ICRP : The international commission on Radiological Protection.
2.3 EC : European Commission recommendation no. 112 , 1999 .
2.4 OECD : Organization Economic and corporation Development .
2.5 MDA : Minimum Detectable Activity.
2.6 Main materials for building :
The building materials used to build the main structures of a building.
2.7 Decorative materials
The building materials used for indoor and outdoor decorations of a building.

2.8 Building

The buildings or indoor spaces, places which are used for humans to carry out production, working, living or other activities. According to the different application purposes of buildings,

2.9 Building Materials

it's the raw materials which comes with another materials to construction purposes e.g., materials raw in cement manufacturing , tiles , ceramic and coating.

2.10 Classification rocks and building materials

According To method of uses the rocks and building materials were classified into :

2.10.1 Main construction rocks

General it used in the building by main parts and we don't change in its properties e.g. texture, shape ,or component during use it.

2.10.2 sub construction materials

we uses it with another materials in construction e.g. the sandstone ,limeston , pumic and gypsum are mixed to manufacturing of cement.

1.1 Fig.2.1: Topo. shows the uses of natural rocks in construction

3 Experimental methods

3.1 Sample collection and preparation

In quarry were collected at 2 -5 sampleswere crushed and mixed in order to bemonolithic and representative to all quarry(table.4.1and Fig.3.1).The selection should be at the depth 0.5 – 1 m ,fresh and size about (1 – 1.5)kg .

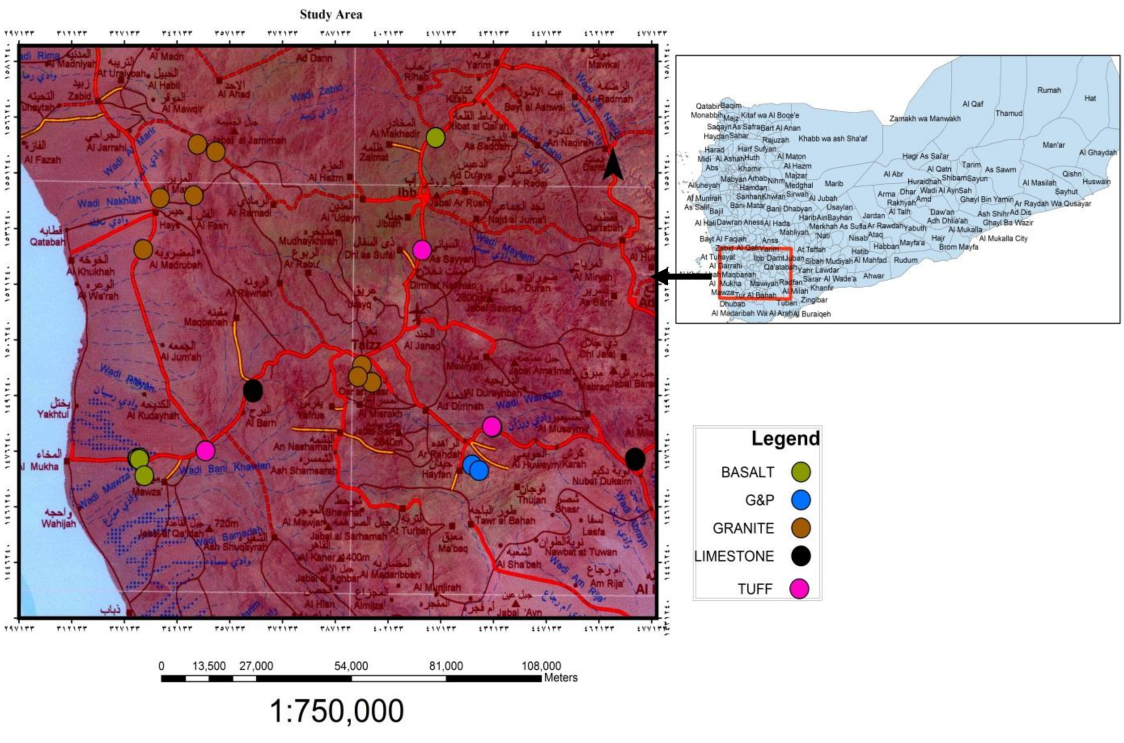


Fig.3.1 :location map shows the samples and their types.

3.2 Preparation samples

Totally of 40 samples of building materials were collected from 11 quarries from 3 different governorates in Yemen(table,3.1and Fig.3.1). The following process for preparation samples :

Firstly, all samples were crushed and grounded. Then, sieved by sieve its mesh about 0.2mm to become uniform in mixture and size to all Particles. afterwards, the samples were put in a container plastic about 500gm and hermetically sealed to prevent the escape of gaseous Rn-222 , Rn-220 and kept them. Afterwards, it were stored to ~ 30 day to allow U-238 , Th-232 decay series to reach to secular equilibrium, finally, the sample were measurement by gamma ray spectrometer high purity germanium(HPGM).

Table.3.1: samples of locations

Name Rock	ELE.m	Y	X	Location.NO.	serial NO.
BASALT	1750	1560819	415656	B-1	1
	1745	1560703	415673		2
	1740	1560740	415618		3
	1770	1560730	415603		4
TUFF	916	1482734	431712	T-1	5
	930	1482674	431866		6
	907	1482971	431618		7
	914	1482898	431616		8
	910	1482852	431627		9
LIMESTONE	537	1473713	472457	LM-1	10
	536	1473947	472486		11
	235	1474145	472602		12
	526	1474383	472333		13
GRANIT	1569	1496336	394646	G-1	14
	2973	1494755	397471		15
	2550	1496316	393527		16
TUFF	353	1476374	350150	T-2	17
	357	1476374	350174		18
	362	1476350	350145		19
	367	1476309	350163		20
BASALT	150	1474222	330720	B-2	21
	180	1474353	330902		22
	207	1474402	331458		23
	165	1474015	331319		24
	215	1469614	332733		25
LIMESTONE	680	1472883	363683	Lm-2	26
	685	1492795	363683		27
	682	1492298	363720		28
	686	1492169	363701		29
GRANIT	149	1530575	332488	G-2	30
	216	1544431	337243		31
	302	1545127	346806		32
	460	1556926	353106		33
	411	1558927	347891		34
TUFF	2115	1530446	411818	T-3	35
	2110	1530444	411786		36
	2110	1530452	411793		37
	2115	1530396	411783		38
SchistGranite	1813	1472500	426000	SG	39
Migmatite	1529	147000	428000	M1	40

3.3 Measurement procedure

The activities of Ra-226, Pb-214 and Bi-214 in equilibrium with their parents were assumed to represent the 238U activity, while the activities of Ac-228, , Pb-212 and Bi-212 were assumed to represent the Th-232 activity. 238U and 232Th activities were calculated using average value of their progeny Ra-226, Pb-214, Bi-214, Ac-228 , Pb-212, Bi-212 and K-40,respectively.Gamma spectrometry measurements were made with high purity Ge detector of 35% relative Efficiency and resolution 1.85 keV at the 1332 keV gamma of Co-60 (Canberra, GC 3518 model). The detector was shielded in a 8 cm thick lead well internally lined with 2mm Cu and 2mm Cd foils. The detector output was connected to a spectroscopy amplifier (Canberra, model 2002CSL). The energy calibration and relative efficiency calibration of the spectrometer were carried out using 200 ml containers, where they were stored for about 1 month to reach the secular equilibrium. Calibration sources which contain Am-241, Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Sr-85, Cs-137, Y88 and Co60 (SRM solution of mixed radioactive nuclides (R8/31/38 QCT48)) was used for the energy and efficiency calibration.

Peaks for energy range between 50 and 2780 kev.The counting time for each sample and background was 64800s. Gamma spectroscopy was used to determine the Activities of U238, Th232 and K40.The activity concentrations of Th232 and U238 were calculated assuming secular equilibrium with their decay products. The gamma ray transitions of energies 186.3 keV (Ra226), 351.9, 296.20 keV (Pb214) and 609.3,1120 keV (Bi214) were used to determine the concentration of the U238 series. The gamma-ray lines at 911.0, 338.4 keV (Ac228) , 583.3 keV, 239 keV (Pb212) and 727.3 keV (Bi212) were used to determine the concentration of the Th232 series. The 1460 keV gamma-ray transition was used to determine the concentration of K40.The activity Levels of the samples obtained for Ra226, Pb214, Bi214, Ac228, Pb212, Bi212 and K40 are expressed in Bq/kg.

4 Discussion and Results

4.1 index 1: Activity concentration

The specific radioactive values of Ra-226 , K-40 and Th-232 Measured in the building materials are shown in (table .4.1,4.2,4.3) respectively. As seen from the (table.4.2) (fig.4.2), the rang of activity k-40(50.68 – 1963.60)Bq/kg , the maximum value was showed in location M1 and the minimum value was showed in location (LM-2). With an average 1083.80 Bq/kg.

The rang of activity Ra-226 in (table.4.1) (fig.4.1,) (MDA – 300.30)Bq/kg. the maximum value was showed in location M1 and the minimum value was showed in location (B -2). With an average 89.47 Bq/kg.

The rang of activity Th-232 in (table.4.3) and (fig.4.1)(MDA – 170.933)Bq/kg. the maximum value was showed in location (M1) and the minimum value was showed in location (LM-2). With an average 63.72 Bq/kg, ± 3.93 Bq/kg.

The samples of Ra-226 (G-1,SG,M1,T-1,T-2,T-3)were obtained higher than the world wide average activity concentration[1]And the location(B-1,B-2,G-2,LM-1,LM-2) were obtained lower than the world average activity concentration of Ra-226 which are **50** Bq/kg. [1]

the location of Th-232 (B-1,B-2,LM-1,LM-2,G-2) were obtained lower the world average activity concentration. [1] And the location(G-1,SG,M1,T-1,T-2,T-3)were obtained higher than the world average activity concentration of Th-232 were higher than the world wide average which are 50 Bq/Kg. [1]

the location of K-40 (B-1,B-2,LM-1,LM-2) were obtained lower the world average activity concentration. And the location(G-1,G-2,SG,M1,T-1,T-2,T-3,G-2)were obtained higher than the world average activity concentration of Th-232 which are 500 Bq/Kg. [1].the variation in activity concentration levels at different samples was due to variation in geological formations.

Table.4.1: activity concentration of Ra-226.Table.4.2 : activity concentration of K-40.

(Bq/kg)±	Ra-226	code sam.
2.90	27.70	B-1
MDA	MDA	B-2
7.10	104.20	G-1
4.90	46.60	G-2
7.90	109.48	SG
17.20	300.30	M1
1.71	17.16	LM-1
2.04	24.05	LM-2
8.20	100.70	T-1
8.90	127.60	T-2
12.20	126.40	T-3
6.64	89.47	AVERAGE
MDA	MDA	MINIMUM
17.2	300.3	MAXIMUM

k-40(Bq/kg)		
(Bq/kg)±	k-40	CodeSam.
12.10	282.30	B-1
5.90	138.50	B-2
76.40	1547.10	G-1
66.80	1315.60	G-2
371.50	1619.35	SG
91.40	1963.60	M1
9.50	153.68	LM-1
3.20	50.68	LM-2
115.00	1875.80	T-1
76.50	1390.90	T-2
93.90	1584.30	T-3
83.84	1083.80	AVERAGE
3.2	50.68	MINIMUM
91.40	1963.60	MAXIMUM

Table.4.3 : activity concentration of Th-232.

±(gk/qB)	hT232(gk/qB)	Code sample
1.133	20.100	B-1
0.433	4.133	B-2
5.467	104.133	G-1
2.900	40.733	G-2
6.767	106.157	SG
8.867	170.933	M1
0.373	1.400	LM-1
MDA	MDA	LM-2
5.700	82.967	T-1
5.767	88.933	T-2
5.867	81.467	T-3
3.93	63.72	AVERAGE
MDA	MDA	MINIMUM
8.867	170.933	MAXIMUM

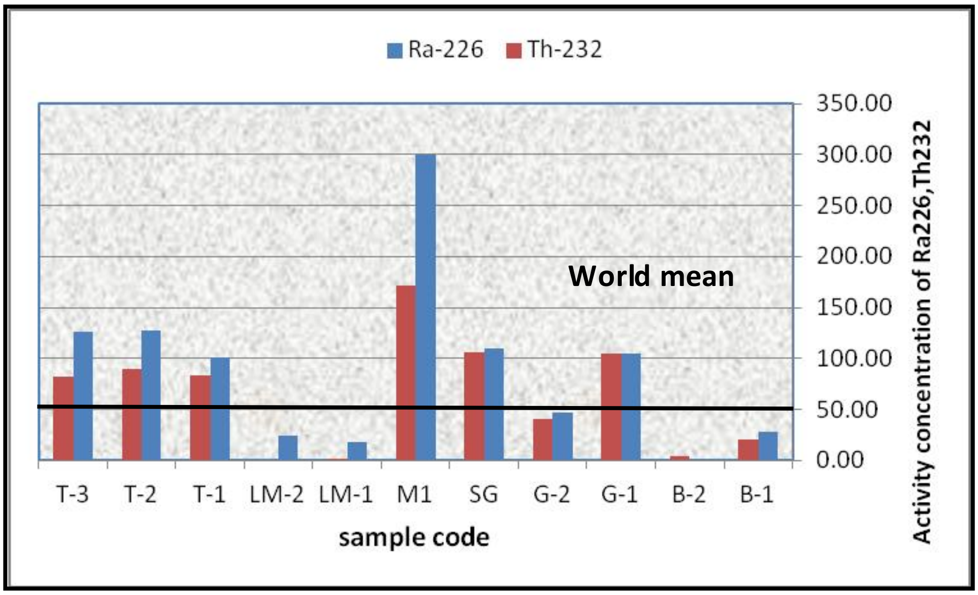


Fig.4.1: Bar graph showing activity concentrations of 226Ra and 232Th.

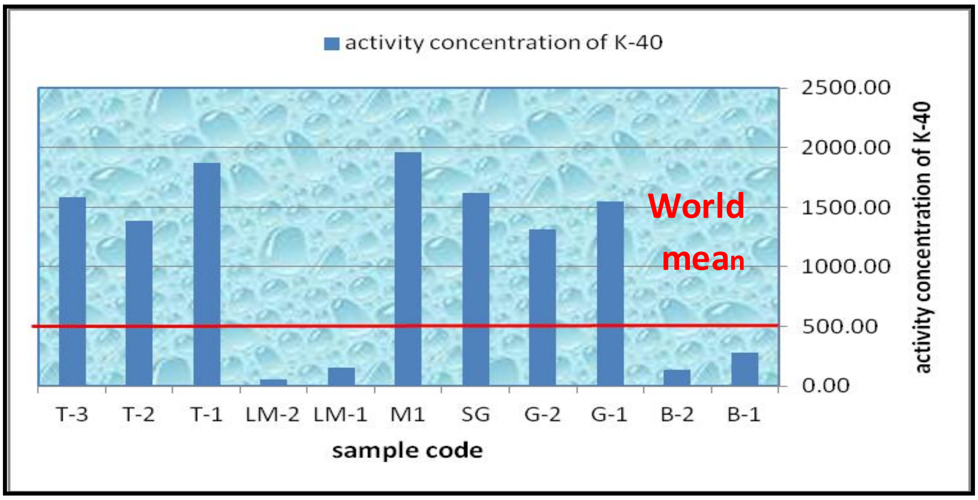


Fig.4.2: Bar graph showing activity concentrations of K-40.

Table .4.4 : Activity concentration of 226Ra,238U,232Th and 40K and its radionuclide in the samples.

u-238(Bq/kg)						Th-232(Bq/kg)						k-40(Bq/kg)		code sam.
(Bq/kg)±	Ra-226	(Bq/kg)±	Bi-214	(Bq/kg)±	pb-214	(Bq/kg)±	Ac-228	(Bq/kg)±	pb-212	(Bq/kg)±	Bi-212	(Bq/kg)±	k-40	
2.90	27.70	0.70	16.20	0.70	16.60	1.00	20.10	1.00	19.70	1.40	20.50	12.10	282.30	B-1
0.00	0.00	0.20	0.00	0.00	0.00	0.40	4.30	0.20	4.20	0.70	3.90	5.90	138.50	B-2
7.10	104.20	2.40	48.80	2.70	51.40	5.10	104.20	5.70	102.50	5.60	105.70	76.40	1547.10	G-1
4.90	46.60	1.40	24.90	1.50	27.80	1.50	28.20	2.70	45.80	4.50	48.20	66.80	1315.60	G-2
7.90	109.48	2.04	47.73	2.40	54.01	7.90	110.87	5.21	102.80	7.19	104.80	371.50	1619.35	SG
17.20	300.30	5.10	110.60	5.60	115.70	7.90	174.30	8.60	163.40	10.10	175.10	91.40	1963.60	M1
1.71	17.16	0.58	7.56	1.30	12.13	0.00	0.00	0.24	3.07	0.88	1.13	9.50	153.68	LM-1
2.04	24.05	0.74	12.58	0.74	14.31	0.00	0.00	0.00	0.00	0.00	0.00	3.20	50.68	LM-2
8.20	100.70	2.90	45.50	3.10	48.60	5.00	79.60	5.30	78.80	6.80	90.50	115.00	1875.80	T-1
8.90	127.60	0.30	41.50	2.70	47.30	4.60	85.90	5.10	84.40	7.60	96.50	76.50	1390.90	T-2
12.20	126.40	3.40	55.60	3.40	61.90	4.30	71.10	5.60	87.40	7.70	85.90	93.90	1584.30	T-3

4.2 Index 2 : Activity concentration index (I)

the European commission guidance document proposes the introduction of an activity concentration index (**I**)[2], it is used to assess the safety requirement of building materials. And there are more than indexes in (Table.4.6) which used in road, street , related to construction work, lanfilling and landscaping.[2]

activity concentration index (I)=ACRa/300 + ACTh/200 + ACK/3000 ≤ 1 (1)

Where AC_{Ra} is the Ra-226 activity concentration Bq/kg, AC_{Th} is the Th-232 activity concentration Bq/kg and AC_{K} is the K-40 activity concentration Bq/kg.

the activity index should not exceed the values in table.4.7,depended on the dose criterion and the manner in a building .[2]

From (table.4.5, and fig.4.3)the values has been founded from (0.07 – 2.51). with the average 0.98 which is below than the world wide average.[2]

the (G-1,SG,M1,T-1,T-2,T-3) had obtained higher than unity and the location (B-1,B-2,G-2,LM-1,LM-2)had obtained more than unity.

Table.4.5: activity concentration index(I) for studied samples.

index (*I*)	(Bq/kg)±	k-40	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	code sam.
0.29	12.10	282.30	1.133	20.10	2.90	27.70	B-1
0.07	5.90	138.50	0.433	4.13	0.00	0.00	B-2
1.38	76.40	1547.10	5.467	104.13	7.10	104.20	G-1
0.80	66.80	1315.60	2.900	40.73	4.90	46.60	G-2
1.44	371.50	1619.35	6.767	106.16	7.90	109.48	SG
2.51	91.40	1963.60	8.867	170.93	17.20	300.30	M1
0.12	9.50	153.68	0.373	1.40	1.71	17.16	LM-1
0.10	3.20	50.68	0.000	0.00	2.04	24.05	LM-2
1.38	115.00	1875.80	5.700	82.97	8.20	100.70	T-1
1.33	76.50	1390.90	5.767	88.93	8.90	127.60	T-2
1.36	93.90	1584.30	5.867	81.47	12.20	126.40	T-3
0.98	83.84	1083.80	3.93	63.72	6.64	89.47	AVERAGE
0.07	3.2	50.68	0.373	1.4	1.71	17.16	MINIMUM
2.51	91.40	1963.60	8.867	170.93	17.20	300.30	MAXIMUM

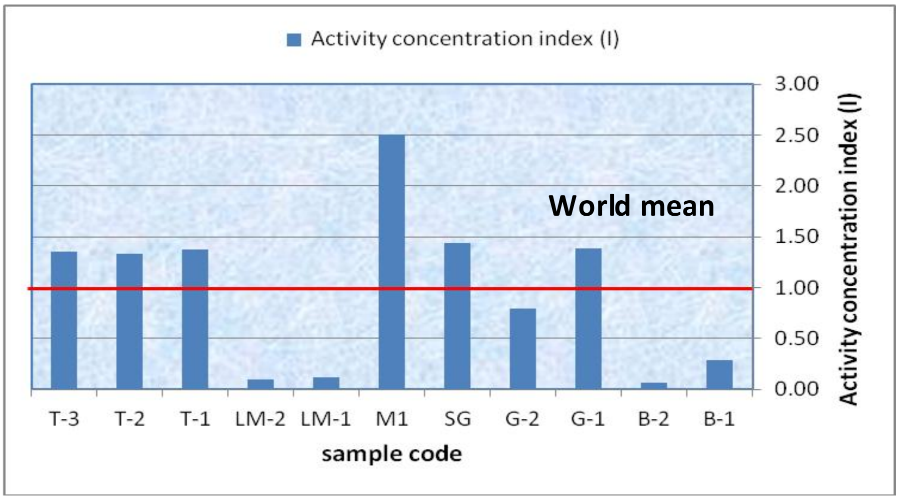


Fig.4.3 . activity concentration index(I) for studied samples.

Table .4.6 : Radioactivity indexes (I) of building materials as a final products and their use.

NO.	Materials	Radioactivity index (I)	(value
1	For Use in house building		
1.1	Materials for use in bulk amounts, e.g. concrete, wall…	(I_1) = CRa/300 + CTh/200 + CK/3000	$I_1 \leq 1$
1.2	Filling materials for use under and near the building		
1.3	Superficial and other materials with restricted use: tiles, boards…		$I_1 \leq 6$
2	Materials for use in road, street and related construction work		
2.1	Materials for use in bulk amounts, e.g. concrete, wall…	I_2 = CRa/700 + CTh/500 + CK/8000	$I_2 \leq 1$
2.2	Superficial and other materials with restricted use: paving...		$I_2 \leq 1{,}5$
3	Materials for use in landfill and landscaping		
3.1	Use in landfill and landscaping	I_3 = CRa/2000 + CTh/1500 +CK/20000	$I_3 \leq 1$
3.2	Must be investigated on the disposal of the material		$I_3 > 1$

Table.4.7: Maximum recommended values of activity concentration index depending on the dose criterion, and the way and the amount the material is used in a building. [2]

dose criterion	**0.3 mSv (annually)**	**1 mSv (annually)**
Materials used in bulk amounts, e.g. concrete	$I \leq 0.5$	$I \leq 1$
Superficial and other materials with restricted use: tiles, boards, etc.	$I \leq 2$	$I \leq 6$

4.3 Index 3 : RADIUM EQUIVALENT INDEX(Ra_{eq})

the distribution of Ra -226 , Th-232 and K-40 in building material is not uniform. Uniformity with respect to exposure to radiation has been defined in term of RadiumEquivalent activity (Ra_{eq}) in Bq/kg to compare the specific activity of containing material different amounts in Ra -226 , Th-232 and K-40. It is calculated by the formula[3]:

$$\text{Radium Equivalent (Raeq) (Bq.kg}^{-1}) = C_{Ra} + 1.43\, C_{Th} + 0.077\, C_K \leq 370 \quad (2)$$

Where C_{Ra} is the Ra-226 activity concentration Bq/kg, C_{Th} is the Th-232 activity concentration Bq/kg and C_K is the activity concentration Bq/kg.

For safe use of building material Radium Equivalent activity (Ra_{eq}) should be less than 370Bq/Kg[4] It is assumed that 370 Bq/kg of Ra-226,259Bq/kg of Th-232 and 4810Bq/Kg of K-40 produce the same gamma-ray dose rate[5].

From the(table.4.8 and figure.4.4) the average values are 264.04 Bq/Kg .The average value of the radium equivalent is less than the safe limits as recommended byOECD.[4] Any Ra_{eq} Concentration value that exceeds 370 Bq / kg may pose radiation hazards.

The highest value of Radium Equivalent is in location(M1,) and the lowest location is in location(B-2).it is observed that the calculated radium equivalent is lower than the recommended maximum value 370 Bq/kg [4]except the values(372.24,385.97,695.93) at location(G-1,SG,M1)respectively was higher than the recommended value and location (G-1) is 372.24 which is near to recommended value. Therefore we recommended that use be construction with some regulation and work a lot of studies at the location(M1,SG). Because the Radium Equivalent index values for these locations exceeded the international standard of 370 Bq/Kg.

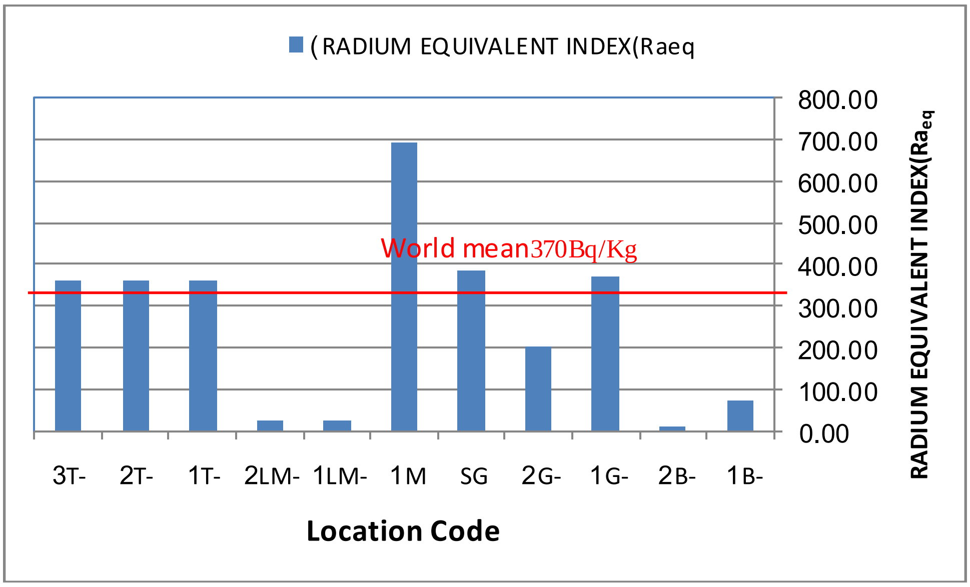


Fig.4.4 : Radium Equivalent index of 226Ra,232Th226Ra and 40K in the sample.

Table.4.8: Radium Equivalent index of 226Ra,232Th226Ra and 40K in the sample.

Ra_{eq}	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	k-40(Bq/kg)		code sam.
					(Bq/kg)±	k-40	
78.18	1.133	20.100	2.90	27.70	12.10	282.30	B-1
16.58	0.433	4.133	0.00	0.00	5.90	138.50	B-2
372.24	5.467	104.133	7.10	104.20	76.40	1547.10	G-1
206.15	2.900	40.733	4.90	46.60	66.80	1315.60	G-2
385.97	6.767	106.157	7.90	109.48	371.50	1619.35	SG
695.93	8.867	170.933	17.20	300.30	91.40	1963.60	M1
31.00	0.373	1.400	1.71	17.16	9.50	153.68	LM-1
27.95	0.000	0.000	2.04	24.05	3.20	50.68	LM-2
363.78	5.700	82.967	8.20	100.70	115.00	1875.80	T-1
361.80	5.767	88.933	8.90	127.60	76.50	1390.90	T-2
364.89	5.867	81.467	12.20	126.40	93.90	1584.30	T-3
264.04							AVERAGE
16.58							MINIMUM
695.93							MAXIMUM

4.4 Index 4 : AbsorbedDoseRateD(nGy.h^{-1})

The absorbed dose rates in air measured 1m above surface of earth's quarry are calculated by Monte Carlo method[6]as:

$$\textit{Dose rate}\ D(nGy.h^{-1}) = 0.462A\,C_{Ra} + 0.621\,AC_{Th} + 0.0417\,A\,C_K \quad (3)$$

Where C_{Ra} is the Ra-226 activity concentration Bq/kg, C_{Th} is the Th-232 activity concentration Bq/kg and C_K is the activity concentration Bq/kg.

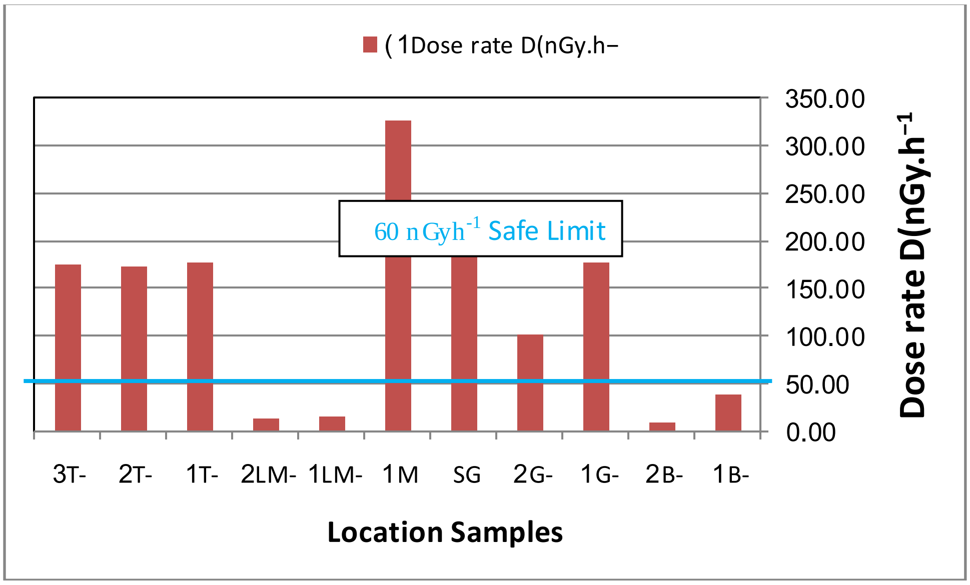
the (table.4.9 and fig 4.5) presented the values . the rang of values are from(8.342 – 326.770) nGy.$h^{-1}$the values (G-1,G-2,SG,M1,T-1,T-2,T-3) were higher than the world average value of 60 nGy.h^{-1}[7]and the values(B-1,B-2,LM-1,LM-2) were below than the world average value of 60 nGy.h^{-1} .

The mean measured absorbed dose rates in all location was 121.653 nGy.h−1 which is higher than the world average value of . [7]

Table.4.9 : Absorbed dose rate index of 226Ra,232Th226Ra and 40K in the sample.

D(nGy.h^{-1})	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	k-40(Bq/kg)		code sam.
					(Bq/kg)±	k-40	
37.051	1.133	20.100	2.90	27.70	12.10	282.30	B-1
8.342	0.433	4.133	0.00	0.00	5.90	138.50	B-2
177.321	5.467	104.133	7.10	104.20	76.40	1547.10	G-1
101.685	2.900	40.733	4.90	46.60	66.80	1315.60	G-2
184.030	6.767	106.157	7.90	109.48	371.50	1619.35	SG
326.770	8.867	170.933	17.20	300.30	91.40	1963.60	M1
15.206	0.373	1.400	1.71	17.16	9.50	153.68	LM-1
13.224	0.000	0.000	2.04	24.05	3.20	50.68	LM-2
176.267	5.700	82.967	8.20	100.70	115.00	1875.80	T-1
172.179	5.767	88.933	8.90	127.60	76.50	1390.90	T-2
126.103	5.867	81.467	12.20	126.40	93.90	1584.30	T-3
121.653	AVERAGE						
8.342	MINIMUM						
326.77	MAXIMUM						

1.2 Fig.4.5 : Absorbed dose rate index of 226Ra,232Th226Ra and 40K in the sample.



4.5 Index 5 : Annual effective doses Equivalent(AEDE):

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7Sv.Gy^{-1}) and outdoor occupancy factor (0.2Sv.Gy^{-1}) proposed by UNSCEAR,[7]are used. Therefore, The world average indoor and outdoor occupancy factors are 0.8 and 0.2 respectively.[7] Therefore, the effective dose rate in units of mSvy^{-1} was estimated using the formula[8]

Indoor effective dose: $E_{ied}(mSvy^{-1}) = D(nGyh^{-1}) \times 8760h.y^{-1} \times 0.8 \times 0.7SvGy^{-1} \times 10^{-6}$ (4)

outdoor effective dose: $E_{oed}(mSvy^{-1}) = D(nGyh^{-1}) \times 8760h.y^{-1} \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6}$ (5)

the annual effective dose equivalent were calculated and listed in (table.4.10and fig.4.6).they were found to be in the rang(0.04-0.9) $mSvy^{-1}$ with an average value 0.619 $mSvy^{-1}$ for indoor effective dose and the annual effective dose equivalent for outdoor were found to be in the rang(0.01 – 0.4) $mSvy^{-1}$ with an average value 0.155 $mSvy^{-1}$ and do not exceed the limits defined inthe recently published European Commission document Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials, Radiation Protection 112, which provides guidance for setting the controls on the radioactivity of building materials in European countries. In table.4.6.
all the values were below than 1 mSv/y which recommended it by(ICRP)[9].The international commission on Radiological Protection has recommended the annual effective dose equivalent limit of 1 mSv/y for the individual members of the public and 20 mSv/y for the radiation workers[9]. excepted the value M1(1.6 mSv/y) which are higher than 1 mSv/y for indoor the annual effective dose equivalent.

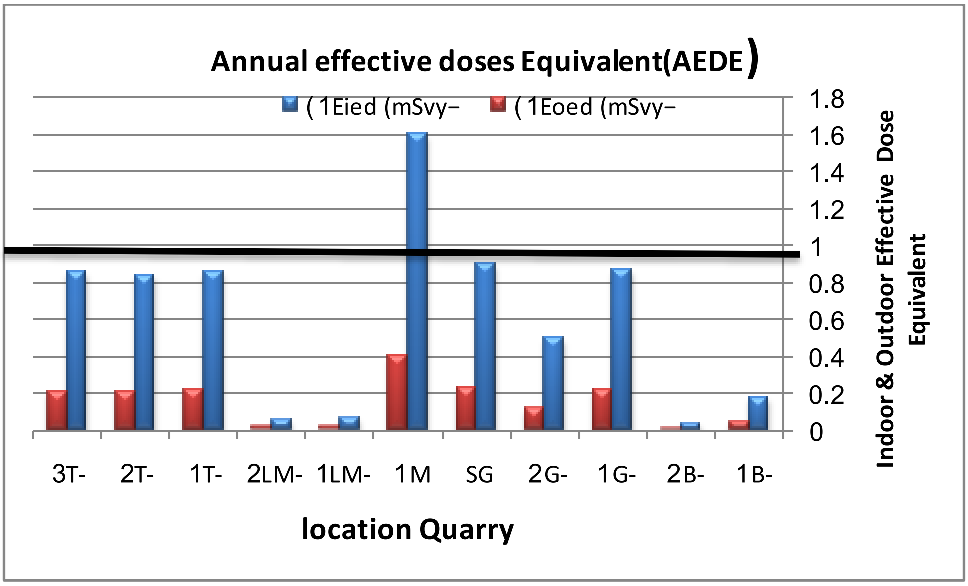


Fig.4.6: Annual effective doses Equivalent(AEDE) for studied sample.

Table.4.10 : Annual effective doses Equivalent(AEDE) for studied sample.

E_{oed} ($mSvy^{-1}$)	E_{ied} ($mSvy^{-1}$)	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	k-40(Bq/kg)		code sam.
						(Bq/kg)±	k-40	
0.05	0.18	1.133	20.100	2.90	27.70	12.10	282.30	B-1
0.01	0.04	0.433	4.133	0.00	0.00	5.90	138.50	B-2
0.22	0.87	5.467	104.133	7.10	104.20	76.40	1547.10	G-1
0.12	0.50	2.900	40.733	4.90	46.60	66.80	1315.60	G-2
0.23	0.90	6.767	106.157	7.90	109.48	371.50	1619.35	SG
0.40	1.60	8.867	170.933	17.20	300.30	91.40	1963.60	M1
0.02	0.07	0.373	1.400	1.71	17.16	9.50	153.68	LM-1
0.02	0.06	0.000	0.000	2.04	24.05	3.20	50.68	LM-2
0.22	0.86	5.700	82.967	8.20	100.70	115.00	1875.80	T-1
0.21	0.84	5.767	88.933	8.90	127.60	76.50	1390.90	T-2
0.21	0.86	5.867	81.467	12.20	126.40	93.90	1584.30	T-3
0.155	0.619	AVERAGE						
0.01	0.04	MINIMUM						
0.4	1.60	MAXIMUM						

4.6 Index 6 : External hazards index(H_{ex})

The External hazards index (H_{ex}) is a radiation hazard defined by(Beretka and Mathew) . to evaluated the radiation indoor dose rate due to the external exposure radiation from natural radiation radionuclide in the construction building materials of dwelling .this index value must be less than unit[10]. to keep the radiation hazard insignificant based on formula. H_{ex}, is defined as[11]:

H_{ex} = AC(Ra)/370+ AC(Th)/259+AC(K)/4810 ≤ 1(6)

Where C_{Ra} is the Ra-226 activity concentration Bq/kg, C_{Th} is the Th-232 activity concentration Bq/kg and C_K is the activity concentration Bq/kg. the maximum value for(H_{ex}) equal to unity corresponds to upper limited of(Ra_{eq})370Bq/Kg.

The value were listed in (table.4.11and fig.4.7)for this study. the values were are obtained from (0.05(B-2) – 1.88(M1)). the maximum value is in location(m1) and the minimum value in location (B-2) respectively, with an average 0.71 for (H_{ex}) which is below than unity[10]. which indicates that the area is no threat of exposure for the population..

4.7

4.8 Table.4.11: Internal Hazard Index (H_{in}) *and* External Hazard Index (H_{ex}) for Studied Samples Used as Building Materials.

H_{in}	H_{ex}	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	k-40(Bq/kg)		code sam.
						(Bq/kg)±	k-40	
0.29	0.21	1.133	20.100	2.90	27.70	12.10	282.30	B-1
0.05	0.05	0.433	4.133	0.00	0.00	5.90	138.50	B-2
1.29	1.01	5.467	104.133	7.10	104.20	76.40	1547.10	G-1
0.68	0.56	2.900	40.733	4.90	46.60	66.80	1315.60	G-2
1.34	1.04	6.767	106.157	7.90	109.48	371.50	1619.35	SG
2.69	1.88	8.867	170.933	17.20	300.30	91.40	1963.60	M1
0.13	0.08	0.373	1.400	1.71	17.16	9.50	153.68	LM-1
0.14	0.08	0.000	0.000	2.04	24.05	3.20	50.68	LM-2
1.25	0.98	5.700	82.967	8.20	100.70	115.00	1875.80	T-1
1.32	0.90	5.767	88.933	8.90	127.60	76.50	1390.90	T-2
1.33	0.99	5.867	81.467	12.20	126.40	93.90	1584.30	T-3
0.95	0.71	AVERAGE						
0.05	0.05	MINIMUM						
2.69	1.88	MAXIMUM						

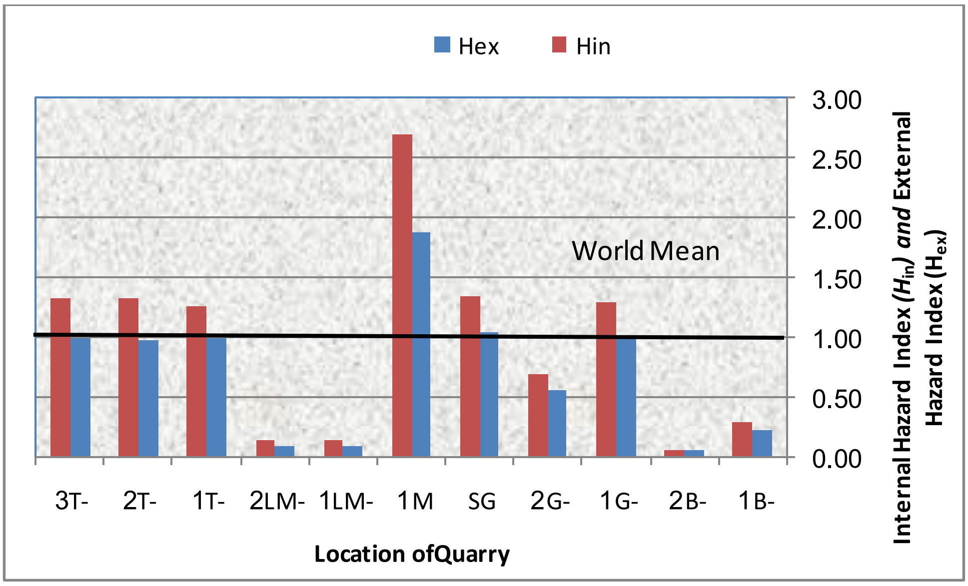


Fig.4.7:Internal Hazard Index (H_{in}) *and* External Hazard Index (H_{ex}) for Studied Samples Used as Building Materials.

4.9 Index 7 : Internal hazards index(H_{in})

Radon and its short- lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the Internal hazards index(**H_{in}**) which is given by the equation as[10]:

H_{in}= AC(Ra)/185+ AC(Th)/259+AC(K)/4810 ≤ 1 (7)

Where C_{Ra} is the Ra-226 activity concentration Bq/kg, C_{Th} is the Th-232 activity concentration Bq/kg and C_K is the activity concentration Bq/kg.
for the safe use of a materials in the construction of dwelling,(H_{in}) should be less than unity[10].
From (table.4.11and fig.4.7) the values range were(0.05 – 2.69) for the location(B-2,M1) respectively. the average values are 0.95 .it is below the internationality accepted value[10]
4.10 Index 8: Radiation Hazard Index or Representative Level Index ($I_{\gamma r}$).
In order to examine whether the samples meets these limits of dose criteria, Another radiation hazard index, the representative level index, *Iγr*, used to estimate the level of *γ*- radiation hazard associated with the natural radionuclides in specific investigated samples, is definedfrom the following Equation[11]:

$$I_{\gamma r} = ACRa/150 + ACTh/100 + ACK/1500 \quad (8)$$

Where C_{Ra} is the Ra-226 activity concentration Bq/kg, C_{Th} is the Th-232 activity concentration Bq/kg and C_K is the activity concentration Bq/kg.
The representative level index values were listed in (table.4.12and figure.4.8) they were varied from0.13 (B-2) mSv/y to 5.02(M1) mSv/y. the location(G-1,G-2,SG.M1,T-1,T-2,T-3) were obtained higher than unity and the location(B-1,B-2,LM-1,LM-2)were obtain below than unity.
The average were 1.96 mSv/y which are higher than 1 mSv/y.[2]

Table.4.12:Radiation Hazard Index of 226Ra,232Th 226Ra and 40K in the sample.

$I_{\gamma r}$	(Bq/kg)±	Th-232(Bq/kg)	(Bq/kg)±	Ra-226	k-40(Bq/kg)		code sam.
					(Bq/kg)±	k-40	
0.57	1.133	20.100	2.90	27.70	12.10	282.30	B-1
0.13	0.433	4.133	0.00	0.00	5.90	138.50	B-2
2.77	5.467	104.133	7.10	104.20	76.40	1547.10	G-1
1.60	2.900	40.733	4.90	46.60	66.80	1315.60	G-2
2.87	6.767	106.157	7.90	109.48	371.50	1619.35	SG
5.02	8.867	170.933	17.20	300.30	91.40	1963.60	M1
0.23	0.373	1.400	1.71	17.16	9.50	153.68	LM-1
0.19	0.000	0.000	2.04	24.05	3.20	50.68	LM-2
2.75	5.700	82.967	8.20	100.70	115.00	1875.80	T-1
2.67	5.767	88.933	8.90	127.60	76.50	1390.90	T-2
2.71	5.867	81.467	12.20	126.40	93.90	1584.30	T-3
1.96	AVERAGE						
0.13	MINIMUM						
5.02	MAXIMUM						

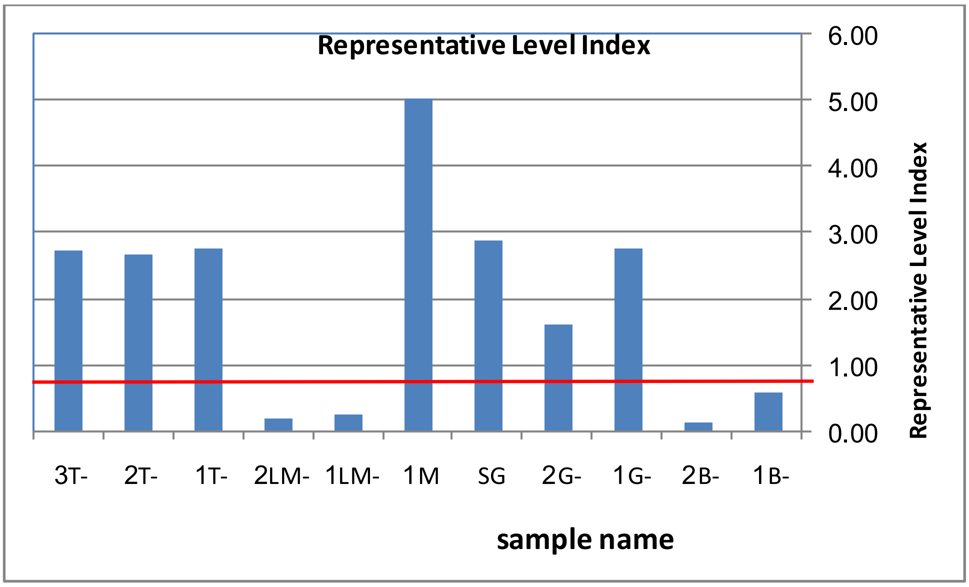


Fig.4.8 :Radiation Hazard Index of 226Ra,232Th and 40K in the samples.

Quarry Code	(I)	(Ra_{eq})	D($nGy.h^{-1}$)	Eo_{ed} ($mSvy^{-1}$)	E_{ied} ($mSvy^{-1}$)	(H_{in})	(H_{ex})	($I_{\gamma r}$)
B-1	0.29	78.18	37.051	0.05	0.18	0.29	0.21	0.57
B-2	0.07	16.58	8.342	0.01	0.04	0.05	0.05	0.13
G-1	1.38	372.24	177.321	0.22	0.87	1.29	1.01	2.77
G-2	0.8	206.15	101.685	0.12	0.5	0.68	0.56	1.6
SG	1.44	385.97	184.03	0.23	0.9	1.34	1.04	2.87
M1	2.51	695.93	326.77	0.4	1.6	2.69	1.88	5.02
LM-1	0.12	31	15.206	0.02	0.07	0.13	0.08	0.23
LM-2	0.1	27.95	13.224	0.02	0.06	0.14	0.08	0.19
T-1	1.38	363.78	176.267	0.22	0.86	1.25	0.98	2.75
T-2	1.33	361.8	172.179	0.21	0.84	1.32	0.9	2.67
T-3	1.36	364.89	126.103	0.21	0.86	1.33	0.99	2.71
AVERAGE	0.98	264.04	121.653	0.155	0.619	0.95	0.71	1.96
MINIMUM	0.07	16.58	8.342	0.01	0.04	0.05	0.05	0.13
MAXIMUM	2.51	695.93	326.77	0.4	1.6	2.69	1.88	5.02

Table.4.13:Radioactivity concentration Index(I),Radium Equivalent(Ra_{eq}) ,Dose Rate(D), Annual effective doses Equivalent(AEDE),External Hazard index(H_{ex}) , Internal Hazard Index(H_{in}), Representative Level Index (Iγr).

5 Biological effects on Radiation

There are three ways which Radio nuclides enter to the human body(Dipak et al.,2008):

1. Direct inhalation of air born particulates, or direct exposure to skin.
2. Ingestion through mouth.
3. Entry by skin.

6 Table.5.1: shows the numbers of cancer cases and cancer risk ratio in quarry.

Cancer Risk Ratio %	D($nGy.h^{-1}$)	Quarry Code
0.08	37.051	B-1
0.018	8.342	B-2
0.381	177.321	G-1
0.218	101.685	G-2
0.395	184.03	SG
0.702	326.77	M1
0.033	15.206	LM-1
0.028	13.224	LM-2
0.379	176.267	T-1
0.37	172.179	T-2
0.271	126.103	T-3

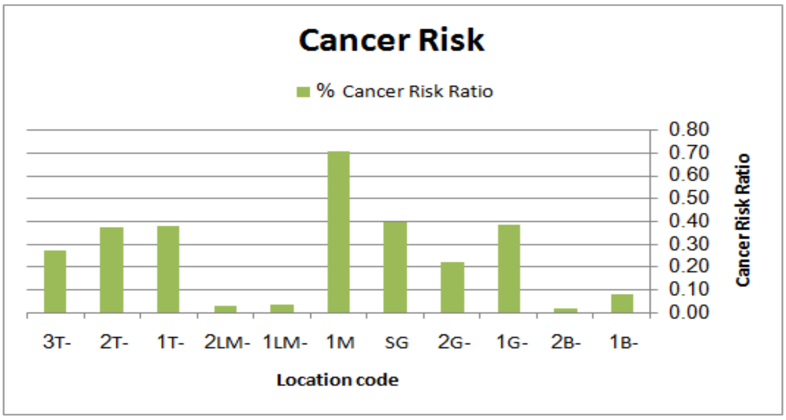


Fig.5.1 par graph shows the cancer risk ratio in quarry.

7 Conclusion

The following conclusion can be drawn from the present investigation:

8 The results of the present work indicate that a lot of quarries in Yemen with a normal level of natural radiation background, and the rocks from the studied area do not pose a significant radiological threat to population when used as construction materials except the quarries Megmatite and Schist-Gneiss

9 From the calculated values, and from the viewpoint radiation It is found that:

i. the quarries which product basalt and limestone are well below the recommended safe limit values, therefore we can use it in construction materials .
ii. For safe use in building materials we don't use Migamatite(M1) and schist-Gneiss rocks(SG) which use locally in some villages in south- west of Yemen, because their all indexes are higher than international standards , therefore the risk(Fig.5.1) will be high due to uses this types of rocks .
iii. The quarry (G-1) products granit are acceptable for uses as superficial building material with some restricted use as countertops and decoration.
3. this work can be used as a baseline data for further research work.
4. Regarding to the Quarries that product Building materials the following points require attention : Safe mode from view point radiation , distance translation , mode of work in quarry ,

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