

Radiological Risk Due to Quantum Pendants

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Abstract: About 45 different quantum accessories (Glass and metallic pendants, cards and bracelets) were collected. Naturally occurring radionuclides ^{238}U , ^{232}Th series and ^{40}K were measured using a high resolution gamma ray spectrometry. Activity concentration levels of the naturally occurring radionuclides were found to be respectively ranged over 1-884, 1-3189 and 1-348Bq for each scalar energy piece. Quantum cards show the highest activity for u-238 and Th-232 series, while, metallic quantum pendants show the highest concentration in K-40. In general, glass quantum pendants show the lowest concentration of all radionuclides. The annual dose rate (mSv/y) due to naturally occurring radionuclides in different types of magnetic pendants, as calculated by Syberad's Health Physicist's Companion program, show that, total annual dose rate received by wearer due to all radionuclides (in 12 hours /day * 365 d/y) at zero distances may be reached to 31 mSv/y for muscle and 30 mSv/y for bone. It can be concluded that quantum pendants lead to overdoses exposure to wearer. The annual effective dose ($\mu\text{Sv/y}$) to worker due to ^{238}U sub-series, ^{232}Th series and ^{40}K was estimated and the maximum values were be respectively 1.05E-09, 1.24E-09 and 2.48E-05 mSv/y due to glass pendants, 8.88E-08, 4.82E-7 and 1.05E-04 mSv/y due to metallic quantum pendants, 1.85E-07, 7.90E07 and 9.43E-05 mSv/y due to scalar energy cards and 1, 47E-05, 4.61E-08 and 7.26E-06 mSv/y due to quantum bracelets. These calculations showed that the highest equivalent dose would be received by skin, due to ^{238}U and ^{232}Th series. The maximum value of the total effective dose to all organs, due to the three natural radionuclides was calculated and it was 4.4E-2mSv/y and the total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, was calculated as 4.29E-2mSv/y. Quantum pendants and cards which made from special mineral stone show the highest risk which corresponds to dose rate higher than 1 mSv/y. Quantum pendants and bracelets which made from crystal and special types of glass show the lowest radiological risk. Finally we can conclude that some types of quantum pendants lead to high dose rate and then high radiological risk.

Key words: Quantum pendants • External exposure • Radiological risk

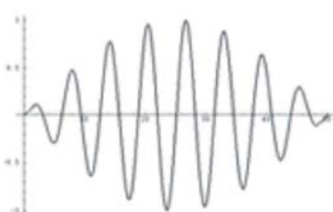
INTRODUCTION

Human beings are exposed to ionizing radiation every day from natural radionuclides in the ground, building materials, air, food, the universe and even elements in their own bodies. The assessment of these doses from natural materials is important as external radiation exposures from natural materials contribute about 50 % of the average annual dose to humans from all radiation sources [1]. The International Atomic Energy Agency (IAEA) defines NORM as a "radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides" and includes "materials in which the activity concentrations of the naturally occurring radionuclides have been changed by a process" [2]. Radioactivity of natural origin is present everywhere, in

the ground we walk on, in the air we breathe and in the water we drink in small amounts. But in portions of some mountains there are very high levels of natural radionuclides such as U-238 and Th-232 series [3- 5]. Each one of these two primordial radionuclides is the head of a series of many radionuclides that produce significant human exposure [6]. Quantum pendant is a wearable handmade accessory made from especially powerful natural energy minerals. It is infused with more than 70 kinds of energy releasing mineral materials that supersedes titanium, organic germanium, tourmaline, birthstone, etc. It is processed under extreme temperature before it is casted to form bio-ceramics under low temperature treatment. These accessories, also called scalar energy accessories. Scalar energy is different from hertzian electromagnetic fields in that rather than being a wave it is more like a field.

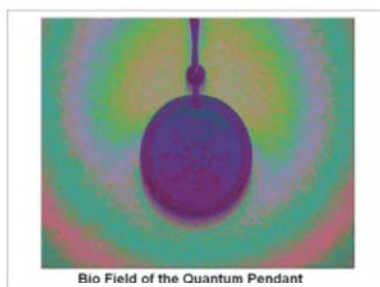


Scalar



Hertzian

So Instead of running along a wire or shooting out in beams it tends to fill it's environment and is capable of passing through solid objects without any loss of intensity [7]. Many people think that these pendants are beneficial to health to the wearer as claimed. Among the claims are the pendant will help increase and improve blood circulation, increase a person's energy, increase immunity, etc. As the radiation dose from a single pendant may reach a valuable percentage of the annual skin dose limit recommended by the ICRP, year-long contact with the pendant may result in radiological risk to skin. So, it is very important aspect to assess the external exposure to wearer through calculation of the external γ - absorbed dose rate in quantum products from measurements of the concentrations of the relevant radionuclides in them. So, the aim of this work is to investigate the spatial distribution of the long-lived radionuclides of the U-238 and Th-232 series in these accessories and calculate the radiological risk on consumer.



MATERIALS AND METHODS

Samples were directly measured by efficiency and energy calibrated HPGe detector. The main characteristics

required for such detection systems are high efficiency, high-energy resolution and very low background. Especially the background features of the system are of considerable importance, as they must be known in order to get an estimate of the detection limits and the minimum detectable activity [8, 9]. HPGe detector is a P-type coaxial detector with active volume of 138 cm³, relative efficiency to NaI (Tl) detector is 30% measured at 1332 keV with source to detector distance of 25 cm. Resolution is 1.9 keV at 1332 keV.

The counting time was between 2 and 6 hours. A calibration was made by using standard calibration sources (powder) of U-238 (RGU-1), with 400 ppm concentration, 1.78 density and activity 4.9 Bq/gm and Th-232 (RGTh-1), with 800 ppm, 1.71 density and activity 3.26 Bq/gm.

To make a decision whether the sample contains activity, A, is then compared with a critical level L_c or minimum significant activity (MSA) which is the activity in a sample which produces a counting rate that may be reliably distinguished from background with 95% confidence intervals [10-12]. MSA is 0.3Bq/kg and 0.5Bq/kg, 0.7 Bq/kg for U-238 Th-232 series and K-40 respectively.

Dose Calculation

Dose to Wearer: The principal dosimetric quantities in radiological protection are the mean absorbed dose in a tissue or organ, D_T, (Gy); the equivalent dose in a tissue or organ, H_T, (Sv) formed by weighting the absorbed dose by the radiation weighting factor (W_R),

$$H_T = D_T W_R \tag{1}$$

and the effective dose, E, (Sv) formed by weighting the equivalent dose by the tissue weighting factor (W_T) and summing over the tissues.

$$E = \sum H_T W_T \tag{2}$$

Dose rate was calculated for wearer using Syberad's Health Physicist's Companion program version 1.4.2. The name of the program executable file is HPC.exe.

Syberad's Health Physicist's Companion is software Compatible with Windows 2000, NT, XP and VISTA. It has Part Number: HP-CD1. This database is a user-friendly software program designed for radiation protection professionals; it is a convenient and easy-to-use software tool for obtaining information about more than 2800 radionuclides. It can be used to calculate:

- Future and past radioactivities for any nuclide in the database,
- Dose rates for any nuclide, at any distance, for any activity or mass and with various types of shielding,
- Radiation and dosimetric quantities,
- Physical properties of more than 2800 radionuclides,
- Serial decay series,
- Radon exposure,
- Absorption coefficient values [13].

Dose rates were calculated for natural radionuclides (U-238, Th-232 and K-40) at zero distance [14, 15].

Dose to Workers: By assuming that the natural energy minerals were uniformly distributed in the factories, so the dose rate to workers can be calculated as follow:

Organ Doses: New calculations of organ doses from external irradiation fields were undertaken by Eckerman and Ryman (DFEXT code) [16]. External dose coefficients were computed at Oak Ridge National Laboratory during the preparation of Federal Guidance Report No. 12. In this software the coefficients represent the dose per unit integrated exposure or the dose rate per unit concentration.

- h_t is the equivalent dose in tissue T per unit integrated exposure.
- e is the effective dose per unit integrated exposure $= \sum W_T h_t$, using W_T from ICRP-60 (17). Where the summation extends over the organs/tissues with explicit W_T , W_{rem} is the weighting factors for the remainder (0.3) and h_{rem} is the committed dose equivalent per unit integrated exposure for the remainder tissues. h_{rem} is given as: $h_{rem} = 1/5 \sum h_t$.

From these coefficients, equivalent dose (H_T) to any organ can be calculated as follow:

$$H_T = \chi * T * 3600 \text{ (sec/hr)}, * h_t \text{ (Sv)} \quad (3)$$

where: χ is the activity concentration in air (Bq),

T is the exposure time (hours), (8hr/d * 5 d / week * 50 week/y)

h_t is the equivalent dose in tissue T per unit integrated exposure (Sv /sec Bq),

While the effective dose (E) can be calculated as follow:

$$E = \chi * T * 3600 * e \text{ (Sv)} \quad (4)$$

where: e (Sv /sec Bq) is the effective dose per unit integrated exposure computed as the: $\sum W_T h_t$, using W_T from ICRP-60 [17].

RESULTS AND DISCUSSION

Activity Concentration in Quantum Accessories Samples: Tables (1-4) show the activity concentration of U-238 series, Th-232 series & K-40 in different quantum accessories (Bq). Results show that, activity concentration distributed over the range of 1 to 884 Bq for u-238, 1 to 3189 Bq for Th-232 and 1 to 348 Bq for K-40. Quantum cards show the highest activity for u-232 and Th-232 series, while, metallic quantum pendants show the highest concentration in K-40. In general, glass quantum pendants show the lowest concentration of all radionuclides.

Tables (5-8) show the annual dose rate (mSv/y) due to naturally occurring radionuclides in different types of magnetic pendants. Results, as calculated by Syberad's Health Physicist's Companion program, show that, total annual dose rate received by wearer due to all radionuclides (in 12 hours /day * 365 d/y) at zero distances may be reached to 31 mSv/y for muscle and 30 mSv/y for bone. It can be concluded that quantum pendants causes overdoses exposure to wearer.

Table 1: Activity concentration of U-238 series, Th-232 series & K-40 in metallic quantum pendants (Bq)

Metallic quantum pendants' activity concentration (Bq)			
Sample no.	U-238	Th-232	K-40
1	26	88	68
2	37	254	69
3	283	1947	348
4	46	295	49
5	54	262	49
6	57	241	84
7	47	221	14
8	21	96	14
9	61	281	49
10	123	494	32
11	34	222	67
12	67	644	52
13	70	376	84
14	17	97	54
15	424	544	41
16	122	576	111
27	120	559	52
18	67	391	53
19	32	103	49
20	18	65	22
21	71	581	1
22	146	714	1
Range	17-424	65-1947	1-348

Table 2: Activity concentration of U-238 series, Th-232 series & K-40 in glass quantum pendants (Bq)

Quantum cards' activity concentration (Bq)			
Sample no.	U-238	Th-232	K-40
1	679	2771	189
2	884	3189	242
3	690	2574	189
4	815	2848	312
5	86	333	24
6	14	202	1
7	87	316	28
Range	14-884	202-3189	1-312

Table 3: Activity concentration of U-238 series, Th-232 series & K-40 in quantum Cards (Bq)

Glass quantum pendants' activity concentration (Bq)			
Sample no.	U-238	Th-232	K-40
1	1	1	82
2	3	1	24
3	5	1	24
4	1	5	68
5	1	1	66
6	3	3	22
Range	1-5	1-5	22-82

Table 4: Activity concentration of U-238 series, Th-232 series & K-40 in Quantum bracelets (Bq)

Quantum bracelets' activity concentration (Bq)			
Sample no.	U-238	Th-232	K-40
1	3	56	1
2	70	186	1
3	5	31	1
4	4	13	24
5	8	63	1
6	3	14	24
7	4	8	14
8	1	16	1
Range	1-70	8-186	1-24

Table 5: Annual dose rate due to U-238 series (mSv/y)

Range of dose (mSv/y) due to U-238			
Pendants' type	Air	Muscle	Bone
Glass	0.00003 - 0.00016	0.00003 - 0.00017	0.00016 - 0.00080
Metallic	0.00050 - 0.01330	0.00060 - 0.01420	0.00270 - 0.06750
Cards	0.00040 - 0.02780	0.00050 - 0.02960	0.00220 - 0.14080
Bracelets	0.00003 - 0.00220	0.00003 - 0.00235	0.00016 - 0.01115

Table 6: Annual dose rate due to Th-232 series (mSv/y)

Range of dose (mSv/y) due to Th-232			
Pendants' type	Air	Muscle	Bone
Glass	0.0001 - 0.0006	0.0001 - 0.0006	0.0005 - 0.0024
Metallic	0.0076 - 0.2269	0.0081 - 0.2439	0.0317 - 0.9480
Cards	0.0235 - 0.3715	0.0253 - 0.3994	0.0984 - 1.5529
Bracelets	0.0009 - 0.0217	0.0010 - 0.0233	0.0039 - 0.0906

Table 7: Annual dose rate due to K-40 (mSv/y)

Pendants' type	Range of dose (mSv/y) due to K-40		
	Air	Muscle	Bone
Glass	1.8089 - 6.7411	1.9943 - 7.4336	1.8628 - 6.9427
Metallic	0.0822 - 28.6122	0.0906 - 31.5445	0.0847 - 29.4669
Cards	0.0822 - 25.6537	0.0906 - 28.2835	0.0847 - 26.4207
Bracelets	0.0822 - 19.7323	0.0906 - 2.1757	0.0847 - 2.0324

Table 8: Annual dose rate due to all natural radionuclides (mSv/y)

Pendants' type	Range of total dose (mSv/y) due to all radionuclides		
	Air	Muscle	Bone
Glass	1.8090 - 6.7418	1.9944 - 7.4344	1.8634 - 6.9459
Metallic	0.0903 - 28.8524	0.0993 - 31.8025	0.1190 - 30.4825
Cards	0.1062 - 26.0530	0.1164 - 28.7125	0.1853 - 28.1144
Bracelets	0.0832 - 19.7561	0.0917 - 2.2014	0.0887 - 2.1341

Table 9: Equivalent and effective doses to different organs and the whole body due to U-238 series, Th-232 series & K-40 in glass pendants

Organ	U-238		Th-232		K-40	
	Min	Max	Min	Max	Min	Max
R Marrow	8.93E-12	4.46E-11	3.97E-11	1.99E-10	1.25E-06	4.64E-06
Adrenals	4.23E-12	2.12E-11	3.25E-11	1.63E-10	1.05E-06	3.92E-06
B Surface	5.33E-11	2.66E-10	1.87E-10	9.36E-10	1.76E-06	6.55E-06
Brain	5.72E-12	2.86E-11	4.35E-11	2.17E-10	1.35E-06	5.02E-06
Breast	6.15E-11	3.07E-10	9.79E-11	4.90E-10	1.40E-06	5.22E-06
G Bladder	3.95E-12	1.97E-11	3.18E-11	1.59E-10	1.07E-06	3.99E-06
Esophagus	3.03E-12	1.52E-11	2.85E-11	1.43E-10	1.09E-06	4.05E-06
ST Wall	5.95E-12	2.97E-11	3.85E-11	1.93E-10	1.13E-06	4.22E-06
SI Wall	3.51E-12	1.76E-11	3.00E-11	1.50E-10	1.05E-06	3.90E-06
ULI Wall	4.05E-12	2.03E-11	3.26E-11	1.63E-10	1.07E-06	4.00E-06
LLI Wall	3.58E-12	1.79E-11	3.04E-11	1.52E-10	1.06E-06	3.95E-06
Heart	5.38E-12	2.69E-11	3.67E-11	1.84E-10	1.13E-06	4.20E-06
Kidneys	7.70E-12	3.85E-11	4.12E-11	2.06E-10	1.14E-06	4.23E-06
Liver	5.83E-12	2.92E-11	3.92E-11	1.96E-10	1.15E-06	4.28E-06
Lungs	7.17E-12	3.59E-11	4.59E-11	2.29E-10	1.25E-06	4.67E-06
Ovaries	3.14E-12	1.57E-11	2.81E-11	1.40E-10	1.08E-06	4.01E-06
Pancreas	3.15E-12	1.57E-11	2.89E-11	1.44E-10	1.04E-06	3.86E-06
Skin	2.10E-10	1.05E-09	2.48E-10	1.24E-09	6.65E-06	2.48E-05
Spleen	5.40E-12	2.70E-11	3.88E-11	1.94E-10	1.15E-06	4.28E-06
Testes	3.16E-11	1.58E-10	6.72E-11	3.36E-10	1.24E-06	4.61E-06
Thymus	8.50E-12	4.25E-11	4.46E-11	2.23E-10	1.20E-06	4.48E-06
Thyroid	1.96E-11	9.79E-11	5.69E-11	2.84E-10	1.28E-06	4.76E-06
U Bladder	5.70E-12	2.85E-11	3.62E-11	1.81E-10	1.07E-06	3.99E-06
Uterus	3.29E-12	1.65E-11	2.89E-11	1.44E-10	1.02E-06	3.82E-06
Muscle	2.66E-11	1.33E-10	5.97E-11	2.98E-10	1.22E-06	4.56E-06
h_rem	2.46E-11	1.23E-10	5.77E-11	2.88E-10	1.22E-06	4.55E-06
e	1.80E-11	9.00E-11	5.21E-11	2.61E-10	1.25E-06	4.68E-06

Tables (9-12) investigate the equivalent and effective doses to different organs and the whole body to workers due to U-238 series, Th-232 series & K-40 in different quantum pendant as calculated by (DFEXT code). These calculations showed that the highest equivalent dose would be received by skin, due to ²³⁸U and ²³²Thseries. The maximum value of the total effective

dose to all organs, due to the three natural radionuclides was calculated and it was 4.4E-2mSv/y and the total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, was calculated as 4.29E-2 mSv/y. metallic quantum pendants and cards which made from special mineral stone show the highest risk which corresponds to dose rate higher than 1 mSv/y.

Table 10: Equivalent and effective doses to different organs and the whole body due to U-238 series, Th-232 series & K-40 in metallic pendants

Metallic ----- Organ	U-238 -----		Th-232 -----		K-40 -----	
	Min	Max	Min	Max	Min	Max
R Marrow	1.52E-10	3.79E-09	2.58E-09	7.74E-08	5.66E-08	1.97E-05
Adrenals	7.20E-11	1.80E-09	2.12E-09	6.34E-08	4.78E-08	1.66E-05
B Surface	9.06E-10	2.26E-08	1.22E-08	3.64E-07	7.99E-08	2.78E-05
Brain	9.73E-11	2.43E-09	2.83E-09	8.47E-08	6.12E-08	2.13E-05
Breast	1.05E-09	2.61E-08	6.36E-09	1.91E-07	6.36E-08	2.21E-05
G Bladder	6.71E-11	1.67E-09	2.07E-09	6.20E-08	4.86E-08	1.69E-05
Esophagus	5.15E-11	1.29E-09	1.85E-09	5.55E-08	4.94E-08	1.72E-05
ST Wall	1.01E-10	2.52E-09	2.50E-09	7.50E-08	5.15E-08	1.79E-05
SI Wall	5.97E-11	1.49E-09	1.95E-09	5.85E-08	4.76E-08	1.66E-05
ULI Wall	6.89E-11	1.72E-09	1.72E-09	6.35E-08	4.87E-08	1.70E-05
LLI Wall	6.08E-11	1.52E-09	1.52E-09	5.92E-08	4.82E-08	1.68E-05
Heart	9.14E-11	2.28E-09	2.28E-09	7.15E-08	5.12E-08	1.78E-05
Kidneys	1.31E-10	3.27E-09	3.27E-09	8.02E-08	5.16E-08	1.80E-05
Liver	9.91E-11	2.47E-09	2.47E-09	7.63E-08	5.22E-08	1.82E-05
Lungs	1.22E-10	3.04E-09	3.04E-09	8.93E-08	5.70E-08	1.98E-05
Ovaries	5.34E-11	1.33E-09	1.33E-09	5.47E-08	4.90E-08	1.70E-05
Pancreas	5.35E-11	1.33E-09	1.33E-09	5.62E-08	4.71E-08	1.64E-05
Skin	3.56E-09	8.88E-08	8.88E-08	4.82E-07	3.02E-07	1.05E-04
Spleen	9.18E-11	2.29E-09	2.52E-09	7.56E-08	5.22E-08	1.82E-05
Testes	5.37E-10	1.34E-08	4.37E-09	1.31E-07	5.62E-08	1.96E-05
Thymus	1.44E-10	3.60E-09	2.90E-09	8.69E-08	5.46E-08	1.90E-05
Thyroid	3.33E-10	8.30E-09	3.70E-09	1.11E-07	5.81E-08	2.02E-05
U Bladder	9.69E-11	2.42E-09	2.35E-09	7.05E-08	4.86E-08	1.69E-05
Uterus	5.59E-11	1.40E-09	1.88E-09	5.62E-08	4.66E-08	1.62E-05
Muscle	4.52E-10	1.13E-08	3.88E-09	1.16E-07	5.56E-08	1.93E-05
h_rem	4.17E-10	1.04E-08	3.75E-09	1.12E-07	5.55E-08	1.93E-05
e	3.06E-10	3.79E-09	2.58E-09	7.74E-08	5.66E-08	1.97E-05

Table 11: Equivalent and effective doses to different organs and the whole body due to U-238 series, Th-232 series & K-40 in quantum bracelets (Bq)

Bracelets ----- Organ	U-238 -----		Th-232 -----		K-40 -----	
	Min	Max	Min	Max	Min	Max
R Marrow	8.93E-12	6.25E-10	3.18E-10	7.39E-09	5.66E-08	1.36E-06
Adrenals	4.23E-12	2.96E-10	2.60E-10	6.05E-09	4.78E-08	1.15E-06
B Surface	5.33E-11	3.73E-09	1.50E-09	3.48E-08	7.99E-08	1.92E-06
Brain	5.72E-12	4.01E-10	3.48E-10	8.09E-09	6.12E-08	1.47E-06
Breast	6.15E-11	4.30E-09	7.83E-10	1.82E-08	6.36E-08	1.53E-06
G Bladder	3.95E-12	2.76E-10	2.55E-10	5.92E-09	4.86E-08	1.17E-06
Esophagus	3.03E-12	2.12E-10	2.28E-10	5.30E-09	4.94E-08	1.19E-06
ST Wall	5.95E-12	4.16E-10	3.08E-10	7.16E-09	5.15E-08	1.24E-06
SI Wall	3.51E-12	2.46E-10	2.40E-10	5.58E-09	4.76E-08	1.14E-06
ULI Wall	4.05E-12	2.84E-10	2.61E-10	6.07E-09	4.87E-08	1.17E-06
LLI Wall	3.58E-12	2.50E-10	2.43E-10	5.65E-09	4.82E-08	1.16E-06
Heart	5.38E-12	3.76E-10	2.94E-10	6.83E-09	5.12E-08	1.23E-06
Kidneys	7.70E-12	5.39E-10	3.29E-10	7.66E-09	5.16E-08	1.24E-06
Liver	5.83E-12	4.08E-10	3.13E-10	7.29E-09	5.22E-08	1.25E-06
Lungs	7.17E-12	5.02E-10	3.67E-10	8.53E-09	5.70E-08	1.37E-06
Ovaries	3.14E-12	2.20E-10	2.25E-10	5.22E-09	4.90E-08	1.18E-06
Pancreas	3.15E-12	2.20E-10	2.31E-10	5.37E-09	4.71E-08	1.13E-06
Skin	2.10E-10	1.47E-08	1.98E-09	4.61E-08	3.02E-07	7.26E-06
Spleen	5.40E-12	3.78E-10	3.10E-10	7.22E-09	5.22E-08	1.25E-06
Testes	3.16E-11	2.21E-09	5.38E-10	1.25E-08	5.62E-08	1.35E-06
Thymus	8.50E-12	5.95E-10	3.57E-10	8.30E-09	5.46E-08	1.31E-06
Thyroid	1.96E-11	1.37E-09	4.55E-10	1.06E-08	5.81E-08	1.39E-06
U Bladder	5.70E-12	3.99E-10	2.90E-10	6.74E-09	4.86E-08	1.17E-06
Uterus	3.29E-12	2.30E-10	2.31E-10	5.37E-09	4.66E-08	1.12E-06
Muscle	2.66E-11	1.86E-09	4.78E-10	1.11E-08	5.56E-08	1.33E-06
h_rem	2.46E-11	1.72E-09	4.61E-10	1.07E-08	5.55E-08	1.33E-06
e	1.80E-11	1.26E-09	4.17E-10	9.70E-09	5.70E-08	1.37E-06

Table 12: Equivalent and effective doses to different organs and the whole body due to U-238 series, Th-232 series & K-40 in quantum cards (Bq)

Cards	U-238		Th-232		K-40	
	Min	Max	Min	Max	Min	Max
R Marrow	1.25E-10	7.89E-09	8.03E-09	1.27E-07	5.66E-08	1.77E-05
Adrenals	5.93E-11	3.74E-09	6.57E-09	1.04E-07	4.78E-08	1.49E-05
B Surface	7.46E-10	4.71E-08	3.78E-08	5.97E-07	7.99E-08	2.49E-05
Brain	8.01E-11	5.06E-09	8.78E-09	1.39E-07	6.12E-08	1.91E-05
Breast	8.61E-10	5.44E-08	1.98E-08	3.12E-07	6.36E-08	1.99E-05
G Bladder	5.52E-11	3.49E-09	6.43E-09	1.01E-07	4.86E-08	1.52E-05
Esophagus	4.24E-11	2.68E-09	5.76E-09	9.09E-08	4.94E-08	1.54E-05
ST Wall	8.33E-11	5.26E-09	7.78E-09	1.23E-07	5.15E-08	1.61E-05
SI Wall	4.92E-11	3.11E-09	6.06E-09	9.57E-08	4.76E-08	1.48E-05
ULI Wall	5.68E-11	3.58E-09	6.59E-09	1.04E-07	4.87E-08	1.52E-05
LLI Wall	5.01E-11	3.16E-09	6.14E-09	9.69E-08	4.82E-08	1.50E-05
Heart	7.53E-11	4.75E-09	7.42E-09	1.17E-07	5.12E-08	1.60E-05
Kidneys	1.08E-10	6.81E-09	8.32E-09	1.31E-07	5.16E-08	1.61E-05
Liver	8.16E-11	5.16E-09	7.91E-09	1.25E-07	5.22E-08	1.63E-05
Lungs	1.00E-10	6.34E-09	9.26E-09	1.46E-07	5.70E-08	1.78E-05
Ovaries	4.39E-11	2.78E-09	5.67E-09	8.95E-08	4.90E-08	1.53E-05
Pancreas	4.40E-11	2.78E-09	5.83E-09	9.21E-08	4.71E-08	1.47E-05
Skin	2.93E-09	1.85E-07	5.00E-08	7.90E-07	3.02E-07	9.43E-05
Spleen	7.56E-11	4.77E-09	7.84E-09	1.24E-07	5.22E-08	1.63E-05
Testes	4.43E-10	2.79E-08	1.36E-08	2.14E-07	5.62E-08	1.75E-05
Thymus	1.19E-10	7.51E-09	9.02E-09	1.42E-07	5.46E-08	1.71E-05
Thyroid	2.74E-10	1.73E-08	1.15E-08	1.81E-07	5.81E-08	1.81E-05
U Bladder	7.98E-11	5.04E-09	7.32E-09	1.15E-07	4.86E-08	1.52E-05
Uterus	4.61E-11	2.91E-09	5.83E-09	9.21E-08	4.66E-08	1.45E-05
Muscle	3.72E-10	2.35E-08	1.21E-08	1.90E-07	5.56E-08	1.73E-05
h_rem	3.44E-10	2.17E-08	1.16E-08	1.84E-07	5.55E-08	1.73E-05
e	2.52E-10	1.59E-08	1.05E-08	1.66E-07	5.70E-08	1.78E-05

CONCLUSION

Activity concentration levels of the naturally occurring radionuclides were found to be respectively ranged over 1-884, 1-3189 and 1-348Bq for each scalar energy piece. Quantum cards show the highest activity for u-238 and Th-232 series, while, metallic quantum pendants show the highest concentration in K-40. In general, glass quantum pendants show the lowest concentration of all radionuclides. The total annual dose rate received by wearer due to all radionuclides (in 12 hours /day * 365 d/y) at zero distances may be reached to 31 mSv/y for muscle and 30 mSv/y for bone. It can be concluded that quantum pendants lead to overdoses exposure to wearer.

The maximum values of the annual effective dose ($\mu\text{Sv/y}$) to worker due to ^{238}U sub-series, ^{232}Th series and ^{40}K were be respectively 1.05E-09, 1.24E-09 and 2.48E-05 mSv/y due to glass pendants, 8.88E-08, 4.82E-7 and 1.05E-04 mSv/y due to metallic quantum pendants, 1.85E-07, 7.90E07 and 9.43E-05 mSv/y due to scalar energy cards and 1, 47E-05, 4.61E-08 and 7.26E-06 mSv/y due to

quantum bracelets. These calculations showed that the highest equivalent dose would be received by skin, due to ^{238}U and ^{232}Th series. The maximum value of the total effective dose to all organs, due to the three natural radionuclides was calculated and it was 4.4E-2mSv/y and the total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, was calculated as 4.29E-2mSv/y. Quantum pendants and cards which made from special mineral stone show the highest risk which corresponds to dose rate higher than 1 mSv/y. Quantum pendants and bracelets which made from crystal and special types of glass show the lowest radiological risk. Finally we can conclude that some types of quantum pendants lead to high dose rate and then high radiological risk.

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