Measurement of background radiation, cosmic ray flux and their hazard parameter of Baghdad city districts

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Abstract

The aim of this work was directed to measure the cosmic ray (CR) flux and the background (BG) absorbed dose rate for districts of Baghdad city. The maximum values of CR flux was 2.01 (particle/cm^2.s) registered for several Baghdad districts and the minimum was 0.403 (particle/cm^2.s) belonging to Al-kadhimiya district, whereas the overall average value was 1.24 (particle/cm^2.s). The BG measurements showed that the maximum absorbed dose was 25 nSv/h belonging to Noab AL-Dhbat district and the minimum absorbed was 19.01 nSv/h observed in Al-Ghadeer district, while the overall average was 22.56 nSv/h, and this value is small than the Iraqi permissible limit, which is restricted by Iraqi Center of Radiation Protection.

The hazard indices, radium equivalent activity (Ra_{eq}), absorbed dose (D), external annual effective dose (EAD), internal hazard index (H_{in}), and external hazard index (H_{ext}), of TBG, were estimated and all the values of these indices are within the allowed international limits.

قياس الخلفية الأشعاعية وفيض الأشعة الكونية ومؤشرات الخطورة في احياء مدينة بغداد

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الخلاصة

الهدف من هذا العمل هو قياس فيض الاشعة الكونية (CR) بصورة مباشرة و الجرعة الممتصة للخلفية الاشعاعية (BG) لأحياء مدينة بغداد. وكانت القيم القصوى لفيض الاشعة الكونية (2.01 جسيمة\سم^2.ثانية) سجلة لعدد من مناطق بغداد وكان الحد الأدنى (403.0 جسيمة /سم^2.ثانية) في منطقة الكاظمية، في حين بلغ متوسط القيمة الإجمالية (1.24 جسيمة\سم^2.ثانية). أظهرت قياسات (BG) أن الحد الأقصى للجرعة الممتصة (25 نانوسيفرت\ساعة) تابعة لمنطقة نواب الظباط وكان الحد الأدنى للجرعة الممتصة (19.01 نانوسيفرت\ساعة) في حي الغدير، في حين كان المعدل العام (22.56 نانوسيفرت\ساعة)، وهذه القيمة صغيرة من الحد المسموح العراقي ومع ذلك، مؤشرات الخطر الإشعاعي، مثل جرعة امتصاص السنوية البشرية (AAD) بسبب (CR)، الراديوم النشاط يعادل (Ra_{eq})، الجرعة الفعالة السنوية الخارجية (EAD)، ومؤشرات الخطورة الخارجية والداخلية H_{in},H_{ex}، وفي مايتعلق ب BG تم حسابها وكانت قيم مؤشرات الخطورة المقدرة ضمن نطاق الحدود الدولية المسموح بها الذي يقتصر من قبل المركز العراقي للحماية من الإشعاع.

Introduction

Natural radioactivity on earth has been in existence ever since the planet was formed and there are about 60 radionuclides present in nature. About 82% of the environmental radiation is from natural sources. Some area of the world, called high background radiation areas (HBRAs), which have anomalously high levels of background radiations. The ionizing radiations are always present in the environment in which all of us are living [1]. Exposure to ionizing radiation originates from two major sources; naturally occurring and manmade sources. Naturally occurring radioactivity present on the earth's crust can be further classified into two distinct source categories such as virgin and modified natural sources. Virgin sources of radiation are of cosmogenic or primordial (terrestrial) origin and have existed on the earth since primordial times. Modified natural sources are mainly from activities like mining, usage of fossil fuel, production of fertilizers or usage of natural materials for building constructions. The latter is known as Technologically Enhanced Natural Radiation (TENR). Natural radiation is the largest contributor to the collective radiation dose to the world population. Relatively constant exposure to the population at a location is the distinctive characteristics of this radiation. However, cosmic rays represents main part of the background radiation and, therefore, one must measure it to stand up about the hazards. Furthermore, the aim of this work is to measure the absorbed dose rate of background radiation (BG) and cosmic rays flux (CR) of Baghdad city districts and there health hazard indices.

The study area; Baghdad city Baghdad is the capital of the republic of Iraq. The population of Baghdad, according to the statistical of the Iraqi Trade ministry, is approximately 7,216,040, which represents the largest city in Iraq [2], the second largest city in the Arab world (after Cairo, Egypt), and the second largest city in the Western Asia (after Tehran, Iran). On the other hand, Baghdad positioned in the central of Iraq and the Tigris River passes from the middle of it and divides it into two parts. The area of Baghdad is about 4555 km^2. Baghdad is located at coordinates latitude 33°18'03.56"N, longitude 44°25'07.11"E, which is located between the coordinates latitude 33°31'53.29" N, longitude 44°20'14.12"E at the entrance of the Tigris River from the north, and coordinate latitude 33°5'74.43"N, longitude 44°31'45.44"E at the exit of the Tigris river from the south. The range of height above sea level of Baghdad is between 29 – 44 m. However, Baghdad city includes fifty three districts as shown in Fig. 1.

The used dosimeter

The dosimeter that used in this work was developed in our laboratory by dependence the procedure of reference[3], which illustrated all the details of design. This developed dosimeter includes two sets of Geiger – Muller (GM) tubes in each set there are three GM tubes arranged in a way to separate between BG and CR. All the measurements have been done with one meter rising from the ground and in order to get accurate measurements, any reading was measured for five times and the overall average was dependent.

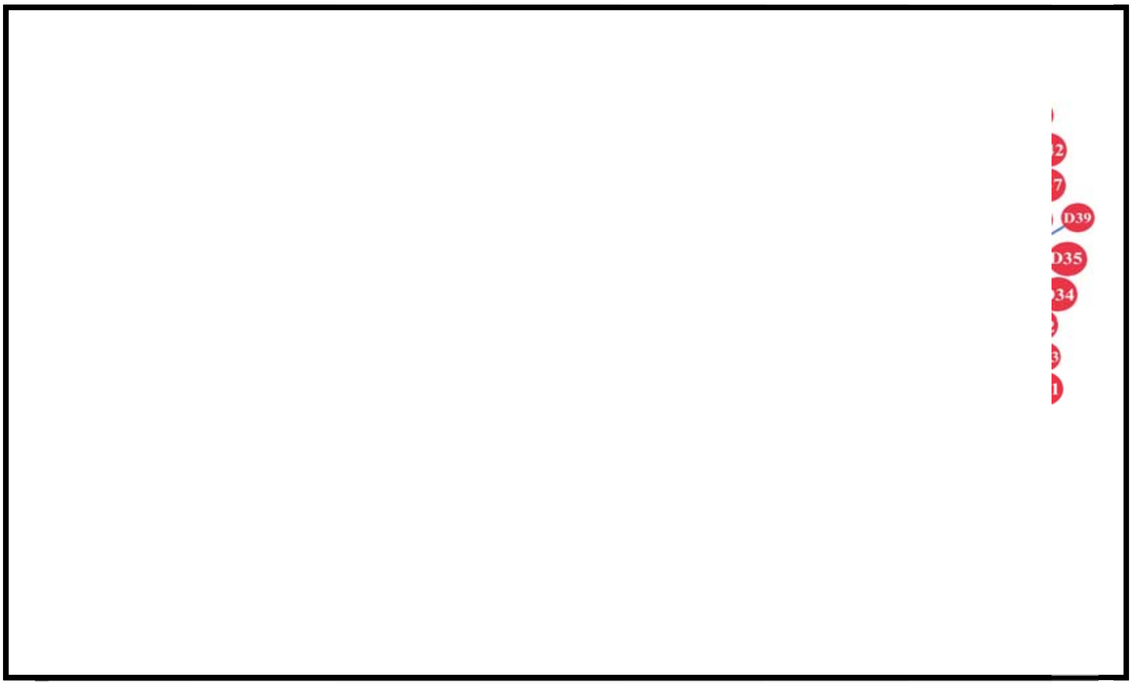

Fig.1: The districts of Baghdad city – Iraq.

The results of BG and CR

The first column in Table 1 shows BG results. The maximum BG was observed in Noab AL-dhbat distract with 25 nSv/h and the minimum was observed in Ghadeer district with 19.01 nSv/h, while the overall average was 22.56 nSv/h. The Iraqi Center of Radiation Protection [4] limited the maximum allowed BG dose about 80 nSv/h, therefore, all the measured results localized within this limit. Many other researchers [5-7] measured BG and the results of this work are within these measurements. For CR flux measurements, the maximum value of CR flux was 2.01×10^{-3} Particle/cm^2.s in AL-Husaniya district and the minimum value was 0.403×10^{-3} Particle/cm^2.s in Kadhimiya district, where as the overall average was 1.24×10^{-3} Particle/cm2.s. In general, the results of CR measurements in all Baghdad city districts are measured and a wide variation in their values were observed, which may be due to the different types of buildings in each district, different weather parameters such as winds, etc. but no direct correlation, has been found from the present data. However, one can attribute these different values of CR to the height measurement from ground level, which was one meter, and for accurate measurements one must measure the CR about 1 km highest at least.

On the other hand, the quantitative biological effects of CR are poorly known, and are the subject of ongoing research. Several experiments, both in space and on Earth, are being carried out to evaluate the exact degree of danger. Experiments in 2007 at Brookhaven National Laboratory's NASA National Space Radiation Laboratory (NSRL) suggested that biological damage due to a given exposure is actually about half what was previously estimated: specifically, it turns out that low energy protons cause more damage than high energy ones [8]. This is explained by the fact that slower particles have more time to interact with molecules in the body. This may be interpreted as an acceptable result for space travel as the cells affected end up with greater energy deposition and are more likely to die without proliferating into tumors with a probability of 10%. However, the health hazardous of CR can be estimated by the unshielded annual absorption dose of human phantom due to CR (AAD) which can be given by [9]:

$$AAD = \{0.53 \times CR\ Flux \times H\ (MeV/cm) \times d\ (cm) \times S\ (cm^2)\} / M(g) \quad (1)$$

where $H \approx 2$ MeV/cm (200 MeV/m) is the stopping power of 1GeV cosmic rays in tissue (water), $d \approx 30$ cm (0.3m) is the average thickness of human torso, $S \approx 7\times10^3$ cm^2 is the average cross-section of human body, M = 70 kg is the approximate mass of an adult astronaut[6]. Further, the last column in table (1) showed the estimated results of AAD. The maximum value of AAD was 64.016 μSv/y and the minimum value was 12.802 μSv/y, while the overall average was 39.276 μSv/y. However, this value of AAD represents about 4% from the total maximum permissible allowed absorbed dose, which is 1 mSv/y [10].

Table 1: The overall results of radiation background, cosmic ray flux, and the unshielded annual absorption dose of human phantom due to cosmic ray for districts of Baghdad city.

District	Location code	Background (BG) (*nSv/h*)	CR Flux (Particle/cm^2.s) × 10^{-3}	Annual Absorption Dose of CR (AAD) (μSv/y)
Shuala	D1	23.96	1.61	51.208
AL-Ghazaliya	D2	24.30	1.61	51.208
AL-Huriyah	D3	22.05	0.805	25.604
AL-Kadhimiya	D4	21.35	0.403	12.802
AL-Tobji	D5	24.65	0.938	29.829
AL-Ataifiya	D6	21.70	1.61	51.208
AL-Washash	D7	24.13	1.07	34.053
AL-Adel	D8	19.61	0.938	29.829
Jamaa district	D9	25.00	1.34	42.630
AL-Muthana st	D10	20.31	1.21	38.406
Haifa st	D11	20.05	0.805	25.604
AL-Mansour	D12	23.26	1.21	38.406
AL-Amerieah	D13	21.52	1.07	34.053
AL-Gadhra	D14	25.69	1.21	38.406
AL-Yarmouk	D15	19.27	1.34	42.630
AL-Amil	D16	19.79	0.805	25.604
AL-Jihad	D17	24.48	0.938	29.829
AL-Bayaa	D18	21.87	1.21	38.406
Shurtah district	D19	22.92	0.938	29.829
AL-Saidiya	D20	23.26	0.938	29.829
AL-Taleem	D21	24.48	1.21	38.406
AL-Dora	D22	22.57	0.938	29.829
Arab Jbor	D23	24.79	1.61	51.208
Abo Deisher	D24	19.96	1.07	34.053
Hor Rajab	D25	19.27	1.61	51.208
Jisr Diyala	D26	21.35	2.01	64.010
AL-Zafraniya	D27	25.00	1.21	38.406
AL-Jadriyah	D28	23.23	2.01	64.010
AL-Karada	D29	25.17	1.34	42.630
Baghdad AL-jadeeda	D30	23.26	1.21	38.406
Noab AL-dhbat	D31	25.00	2.01	64.010

District	Location code	Background (BG) (*nSv/h*)	CR Flux (Particle/cm^2.s) × 10^{-3}	Annual Absorption Dose of CR (AAD) (μSv/y)
AL-Amin	D32	24.48	1.61	51.208
AL-Ghadeer	D33	19.01	0.805	25.604
Muthana district	D34	25.00	1.21	38.406
AL-Mashtal	D35	22.39	0.805	25.604
Bab Sharqi	D36	23.96	0.805	25.604
AL-Fdhel	D37	24.48	1.61	51.208
AL-Baladiyat	D38	20.83	0.805	25.604
AL-Kamaliyah	D39	20.83	0.805	25.604
Bab AL-Moatham	D40	22.39	1.21	38.406
Falastin st	D41	24.48	1.61	51.208
AL-Ubaidi	D42	19.79	1.21	38.406
AL-Adamiyah	D43	23.78	1.21	38.406
AL-Wazireya	D44	21.35	2.01	64.013
Jamila	D45	22.92	1.21	38.406
AL-Sadr city	D46	24.48	0.805	25.604
Saba Abkar	D47	20.31	2.01	64.011
Ur district	D48	23.96	1.21	38.406
AL-Baunk	D49	21.35	1.61	51.208
AL-Sulaikh	D50	22.39	1.21	38.406
AL-Shaab	D51	23.96	0.668	21.251
AL-Sada	D52	19.79	0.805	25.604
AL-Husaniya	D53	20.31	2.01	64.016
The overall average		**22.56**	**1.24**	**39.276**

In order to show the contribution of CR relative to BG, the dose rate due to CR was measured for all study area. Fig. 2 illustrated the ratio between BG and CR dose rates. The maximum value of BG to CR ratio was 41 for Al-Kadhimiya district (which represents the minimum contribution of CR) and the minimum value was 7.8 for Saba Abkar district and AL-Husaniya district (which represents the maximum contribution of CR), while the overall average value was 14.12.

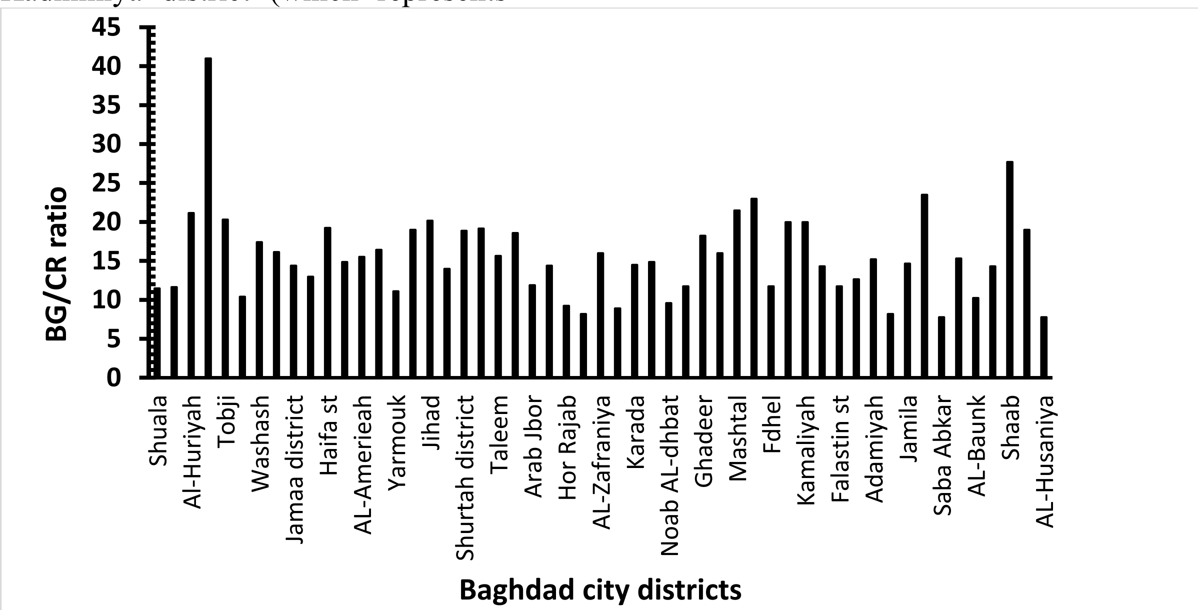

Fig. 2: The BG to CR dose rates ratio for Baghdad districts.

BG Radiation hazard indices

The terrestrial BG (TBG) was estimated by subtracted the CR absorbed dose rate contribution from the total BG measurements. The second column of Table 2 shows the results of TBG which indicate that the maximum value was 24.13 nSv/h in AL-Gadhra district and the minimum value was 17.19 nSv/h in Hor Rajab district, where as the overall average value was 20.96 nSv/h. Nevertheless, the researchers in reference [7] measured the activity concentrations of the NORM isotopes in soils (Natural Occurring Radioactive Materials which are ^{238}U, ^{232}Th, and ^{40}K) for some districts of Baghdad city using gamma spectroscopy, and calculated the hazard indices, which are radium equivalent activity (Ra_{eq}), absorbed dose rate (D), external annual effective dose (EAD), internal hazard index (H_{in}), and external hazard index (H_{ext}). However, in this work the results of the hazard indices of the above reference [7] were plotted against D and some useful fitting equations were obtained. These deduced fitting equations were used to estimate the hazard indices of our TBG results. The definition of these hazard indices and the explanation of the results can be showed as follow:-

Radium equivalent activity (Ra_{eq})

To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclides ^{238}U, ^{232}Th and ^{40}K and is given by the expression[11]:

$$Ra_{eq}\ (Bq/kg) = A(U) + 1.43A(Th) + 0.077A(K) \qquad (2)[11]$$

where, A(U), A(Th) and A(K) are the specific activities concentrations of ^{238}U, ^{232}Th and ^{40}K in (Bq/kg) respectively.

However, Fig. 3a shows the Ra_{eq} as a function of D and from it, the following fitting equation was deduced;

$$Ra_{eq} = 2.1371\ Dose\ \left({}^{nSv}/_{h}\right) + 1.0272 \qquad (3)\ [11]$$

The third column of Table 2 gaves the estimated results of Ra_{eq} of this work for TBG. The maximum value was 52.59 Bq/kg of AL-Gadhra district and the minimum value was 37.76 Bq/kg of Hor Rajab district, while the overall average was 45.82 Bq/kg. Furthermore, all the estimated values of Ra_{eq} are within the allowed permissible limits of global limits [12], which is 370 Bq/kg.

External Annual Dose (EAD)

The external annual effective dose (EAD) was calculated using the following equation [11]:

$$EAD\ (mSv/y) = \{0.92\ A(U) + 1.1\ A(Th) + 0.08\ A(K)\} \times (10^{-9}\ Gy/h) \times (0.7\ Sv/Gy) \times (24 \times 365\ h/y) \times 0.8 \qquad (4)$$

Fig. 3b shows the EAD as a function of D and from this figure the following linear fitting equation was deduced;

$$EAD = 0.0157\ D - 0.0112 \qquad (5)$$

The fourth column of Table 2 illustrates the EAD values of the TBG of this work deduced by Eq. (5). The maximum value was 0.368 mSv/y for AL-Gadhra district and the minimum value was 0.259 mSv/y for Hor Rajab district, whereas the overall average value was 0.318 mSv/y. However, all the estimated values were within the global limits [13], which is 1.5 mSv/y.

The external and internal hazard indices

The widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows [13]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \qquad (6)$$

In addition to external hazard index, the internal exposure to NORM isotopes and its daughter's product is quantified by the internal hazard index H_{in}, which is given by [13]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \qquad (7)$$

The values of the indices (H_{ex}, H_{in}) must be less than unity ($\leq$ 1) for the radiation hazard to be negligible [13]. However, Figs. 3c and 3d showed H_{ex} and H_{in} as functions of D, and from these figures one can deduce the following fitting equations;

$$H_{ex} = 0.0096\,D - 0.0022 \qquad (8)$$

$$H_{in} = 0.0155\,D - 0.0036 \qquad (9)$$

The last two columns of Table 2 gave the estimated results of H_{ex} and H_{in} that were calculated using Eqs. (8) and (9). The maximum values of H_{ex} and H_{in} were 0.229 and 0.378 of D14 district, and the minimum values were 0.163 and 0.270 of D25 district, whereas the overall averages were 0.199 and 0.328, respectively. Although the results of H_{ex} and H_{in} are below unity (which means within the allowed limits), the results showed that H_{in} values higher than H_{ex} and this means the TBG radiation hazard must give more attention.

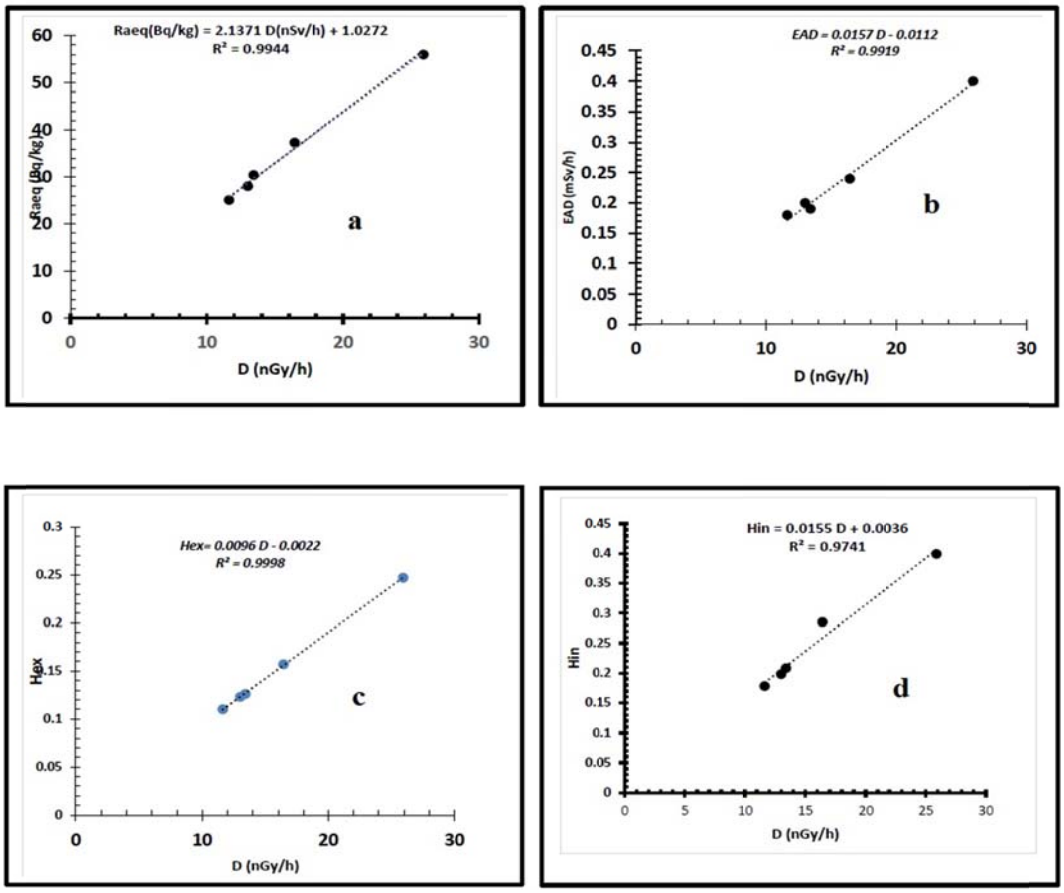

Fig. 3: The hazard indices (a) Ra_{eq},(b) EAD, (c)H_{ext}, and (d)H_{in} as function of D. where the data in this figures were taken from [7].

Table 2: The overall results of Terrestrial BG (TBG) and its hazard indices for districts of Baghdad city.

Location code	TBG (nSv/h)	Ra_{eq}(Bq\kg)	EAD (mSv/y)	H_{in}	H_{ex}
D1	21.87	47.77	0.332	0.343	0.208
D2	22.22	48.51	0.338	0.348	0.211
D3	21.00	45.91	0.319	0.329	0.199
D4	20.83	45.55	0.316	0.326	0.198
D5	23.44	51.11	0.357	0.367	0.223
D6	19.61	42.94	0.297	0.308	0.186
D7	22.74	49.63	0.346	0.356	0.216
D8	18.40	40.35	0.278	0.289	0.174
D9	23.26	50.74	0.354	0.364	0.221
D10	18.75	41.10	0.283	0.294	0.178
D11	19.01	41.65	0.287	0.298	0.180
D12	21.70	47.39	0.329	0.340	0.206
D13	20.14	44.07	0.305	0.316	0.191
D14	24.13	52.59	0.368	0.378	0.229
D15	17.54	38.50	0.264	0.275	0.166
D16	18.75	41.10	0.283	0.294	0.178
D17	23.26	50.74	0.354	0.364	0.221
D18	20.31	44.43	0.308	0.318	0.193
D19	21.70	47.41	0.330	0.340	0.206
D20	22.05	48.14	0.335	0.345	0.209
D21	22.92	50.00	0.349	0.359	0.218
D22	21.35	46.66	0.324	0.335	0.203
D23	22.71	49.55	0.345	0.356	0.216
D24	18.58	40.73	0.280	0.292	0.176
D25	17.19	37.76	0.259	0.270	0.163
D26	18.75	41.10	0.283	0.294	0.178
D27	23.44	51.11	0.357	0.367	0.223
D28	20.62	45.10	0.313	0.323	0.196
D29	23.44	51.11	0.357	0.367	0.223
D30	21.70	47.39	0.329	0.340	0.206
D31	22.39	48.89	0.340	0.351	0.213
D32	22.39	48.89	0.340	0.351	0.213
D33	17.97	39.43	0.271	0.282	0.170
D34	23.44	51.11	0.357	0.367	0.223
D35	21.35	46.66	0.324	0.335	0.203
D36	22.92	50.00	0.349	0.359	0.218
D37	22.39	48.89	0.340	0.351	0.213
D38	19.79	43.32	0.300	0.310	0.188
D39	19.79	43.32	0.300	0.310	0.188
D40	20.83	45.55	0.316	0.326	0.198
D41	22.39	48.89	0.340	0.351	0.213
D42	18.23	39.98	0.275	0.286	0.173
D43	22.22	48.51	0.338	0.348	0.211
D44	18.75	41.10	0.283	0.294	0.178
D45	21.35	46.66	0.324	0.335	0.203
D46	23.44	51.11	0.357	0.367	0.223
D47	17.71	38.87	0.267	0.278	0.168
D48	22.39	48.89	0.340	0.351	0.213
D49	19.27	42.21	0.291	0.302	0.183
D50	20.83	45.55	0.316	0.326	0.198
D51	23.09	50.38	0.351	0.362	0.219
D52	18.75	41.10	0.283	0.294	0.178
D53	17.71	38.87	0.267	0.278	0.168
The overall average	20.96	45.82	0.318	0.328	0.199

Conclusions

According to this work, some important conclusions can be deduced;

- The overall average of CR absorbed dose was 1.6 nSv/h, and the overall average of CR flux was 1.24 Particle/cm^2.s.
- To stand up about the health hazards of CR, the unshielded annual absorption dose of human phantom due to CR was estimated and the overall average value of it was 39.276 μSv/y.
- The overall average ratio of BG to CR was 14.12 and this reflects that the contribution of CR absorbed dose rate to BG is about 7 %, and the residual represents the terrestrial BG (TBG) absorbed dose rate.

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