AFGHAN MEDICAL JOURNAL
KABUL UNIVERISITY OF MEDICAL SCIENCES ABU ALI IBN SINA
Volume 2, Issue 2 | August 2025 AMJ e-ISSN: 3007-0805

ASSESSMENT OF ENVIRONMENTAL RADIATION LEVELS IN DIFFERENT REGIONS OF KABUL CITY

Dad Mohammad Behrooz Naasiri[1] , Ahmad Wali Amini[2], Abdul Qudoos Ahmadi[3], Khair Mohammad Mohammadi[4]
[1,2] Department of Medical Physics, Faculty of Allied Health, Kabul University of Medical Sciences
[3]Department of Community Health, Faculty of Nursing, Kabul University of Medical Sciences
[4] Department of Epidemiology and Biostatistics, Faculty of Public Health, Kabul University of Medical Sciences

Abstract

Background: Environmental gamma radiation of natural origin can cause the ionization of vital molecules such as DNA and pose a serious risk to human health. Measuring this radiation is particularly important because it increases the risk of various cancers. This study was conducted to measure the radiation dose, calculate the annual effective dose, and assess the risk of cancer caused by radiation in different regions of Kabul City in ۲۰۲۴.

Methods: In this study, measurements were taken using a dosimeter (model PM1621A) in open and closed spaces in 6 districts of Kabul city (District 3, District 5, District 6, District 10, District 11, and District 15 of Kabul city) during three different seasons in the Spring, Summer, and Autumn Seasons. Measurements were taken from five areas in each region and five random points in each region over three days in the Spring, Summer, and Autumn seasons. The annual effective dose and lifetime risk of radiation-induced cancer were also calculated.

Results: The average annual dose in open and closed spaces was 1.292±0.163 and 1.4046±0.219 mSv/year, respectively. No statistically significant difference was observed between the average dose values of the Spring, Summer, and Autumn months and different regions of the districts. Also, the annual effective dose was calculated to be 0.93016 millisieverts, and the excess lifetime risk of radiation-induced cancer was calculated to be: 2.7×10^{-3}.

Conclusion: The average annual effective dose of environmental gamma radiation in Kabul City is significantly higher than the global average. It is approximately twice the worldwide average level, indicating a relatively increased potential risk to public health.

Keywords: Background radiation, Kabul city, radiation effects, gamma rays, incidence of cancer risk.

Introduction

Humans are continuously and inevitably exposed to ionizing radiation from their surrounding environment. This ionizing radiation can cause ionization in vital molecules such as DNA and other cellular macromolecules, increasing the likelihood of various cancers and genetic damage, thereby posing a serious threat to human health[13].

Contrary to popular belief, approximately half of the ionizing radiation received by the public originates from natural background radiation, while the remaining portion results from exposure to artificial sources such as diagnostic and therapeutic applications, industrial uses, and others [20]. Natural background radiation includes environmental and cosmic radiation. Among the major sources of environmental radiation are gamma rays emitted from the radioactive nuclei of thorium-232 (^{232}Th), potassium-40 (^{40}K), and uranium-238 (^{238}U), which naturally exist in soil and rocks. On the other hand, primary cosmic radiation, which consists mainly of protons, interacts with nuclei in the upper layers of the atmosphere, producing secondary radiation that reaches the Earth's surface in the form of mesons, electrons, and other particles[13, 20, 22]. The amount of background gamma radiation originating from rocks and soil, as well as cosmic radiation, varies depending on time and geographical location. Additionally, the intensity of cosmic radiation depends on geographic latitude and altitude above sea level [22] On the other hand, the highest doses of gamma radiation emitted from radioactive nuclei are generally found in areas with soils that have high concentrations of uranium and thorium, originating from granite rocks. Additionally, the activity levels in volcanic rocks are usually higher than in sedimentary rocks. However, as an exception, some types of sedimentary rocks, such as certain shale and phosphate rocks, can be highly radioactive[(23 − 24]).

Various studies have reported the levels of background gamma radiation from natural sources for the assessment of the annual effective dose to the population in both outdoor and indoor environments. The global average gamma dose rate in outdoor environments has been reported as 59 nanoseiverts per hour, with a range of 20 to 200 nanoseiverts per hour[1,24]. In Asia, the highest outdoor gamma dose rate has been recorded in Malaysia, and the highest indoor dose rate in Hong Kong, with average values of 175 and 200 nanoseiverts per hour, respectively. The high indoor dose rate in Hong Kong reflects the widespread use of building stones in the country's construction structures[ ]. In Iran, numerous studies have been

1 **Corresponding Author.** Dad Mohammad Behrooz Naasiri
Email: dadmohammadbehrooz@gmail.com
Phone: +93 786681991

Received 23 Jun 2025; Received in revised form 15 July 2025; Accepted 03 August 2025; published Online 25 August 2025.

conducted in various cities such as Lorestan, Tehran, Gilan, Yazd, Ardabil, Hamedan, Ramsar, and Zanjan, reporting different levels of natural background gamma dose rates[12, 19]. The results of studies related to the measurement of natural background gamma dose rates and the calculation of the annual effective dose can be useful for assessing the excess cancer risk caused by such radiation in the population and for analyzing the findings of related epidemiological studies on cancer. Furthermore, documenting the data from these studies helps in detecting any potential changes in environmental radioactivity due to nuclear, industrial, or other human activities[22]. Due to the importance of this issue, the present study was conducted to determine the natural background gamma dose rate, calculate the annual effective dose, and estimate the excess cancer risk caused by this radiation among the residents of Kabul City.

Materials and Methods

This cross-sectional study was conducted in 2024 in different regions of Kabul city. The environmental radiation dose was measured using a POLIMASTER environmental radiometer, model PM1621, manufactured in the United States. The device has a dose rate measurement range of 0.1 mSv/h to 0.1 Sv/h, a dose range of 1.0 mSv to 9.99 Sv, and an energy range of 0.01 to 20 MeV. This dosimeter is highly sensitive to gamma and X-ray radiation levels. In both outdoor and indoor

population density and geological characteristics, and according to international standards and the geographic map of Kabul, measurements were made. Kabul City is situated between latitudes 34.15°N and 34.91°N and longitudes 68.83°E to 69.95°E. The city lies at an elevation of approximately 2803 meters above sea level [2].

The study included various locations across the districts of Kabul city (District 3 includes Karte Char, Deh Bori, Alawuddin Square, Pul-e-Surkh, and Karte Sakhi; District 5 includes Company, Deh Araban, Kote Sangi, Afshar, and Qala-e-Wazir, District 6 includes Qala-e-Shada, Qala-e-Bahadur Khan, Gul Khana, Darulaman, and Chahar Qala Chahar Dehi; District 10 includes Char Qala Wazirabad, Qala Musa, Bibi Mahro, Qala-e-Fathullah, and Wazir Akbar Khan; District 11 includes Hazarah Baghla, behind the 315th Corps, Pustin Dozan Alley, and Kohistan Road; and District 15 includes Khwaja Bughra, Qasaba, Khwaja Rawash, Khwaja Bughra Hill, and the 500 Family area.) It was conducted over three seasons on the dates 2024/3/28 (Spring), 2024/6/29 (Summer), and 2024/10/30 (Autumn).

In the open air, five areas were randomly selected from each area, five points were selected from each area, and data were collected from these five points over one day in three seasons.

In a closed space, five houses were randomly selected from each area, and data were obtained from 25 houses in each area. In each measurement area, because the amount of environmental radiation changes slightly over time, 30 measurements were taken over half an hour with a reading interval of one minute, and the data values were recorded in a checklist[10,8]. Then, the mean and standard deviation of all recorded data were obtained using the SPSS statistical software version 25, and the statistical difference between the means was examined using the analysis of variance test. Statistically, mean differences with p-values less than 0.05 were considered significant. According to the standard protocol, to measure gamma radiation dose in open space, the dosimeter was placed in a north-south direction at a height of 1 meter above the ground and a minimum distance of 5 meters from any building or wall. On the other hand, to measure the dose in a closed space, the dosimeter was placed at a distance of 1 meter from the ground and inside the building. Also, the annual effective dose was calculated using the following formulas:

1. The formula for an annual effective dose of outdoor radiation ($AED_{out} = D_{out} \times T \times OF \times$ the conversion coefficient**).**
2. The formula for an annual effective dose of indoor radiation ($AED_{in} = D_{in} \times T \times OF \times$ the conversion coefficient**).**
3. Annual effective dose formula for outdoor and indoor use ($AED_{total} = AED_{in} + AED_{out}$)

Where AED_{total} is the total annual effective dose in millisieverts, AED_{in} and AED_{out} are the annual effective dose from closed and open waste in millisieverts, respectively, D_{in} and D_{out} are the dose amounts in open and closed spaces, T is the conversion factor from hours to year equal to 8760, OF is the occupancy factor (the entire day and night that a person spends in a specific location), which is considered to be 0.2 for open spaces and 0.8 for closed spaces[24, 8]. In the measurement process, Dout and Din are directly multiplied by T, and their final value is substituted into the formula. Also, the conversion coefficient of absorbed dose in air to effective dose for adults was considered equal to 0.7, according to the recommendation of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [5].

AED_{out} = ۱/۲۹۲ × ۰/۲ × 0.7 = 0.18088

AED_{in} = ۱/۴۰۴۶ × ۰/۸ × ۰/۷ = ۰/۷۴۹۲۸

AED_{total} = 0.18088 + ۰.۷۴۹۲۸ = 0.93016

Also, the excess risk of cancer due to radiation was calculated using the following formula:

Radiation-induced cancer risk formula ($ELCR = AED \times DL \times RF$)

Where ELCR is the excess lifetime risk of cancer due to radiation, AED is the annual effective dose in millisieverts per year, and DL is the life expectancy in years, which according to the World Health Organization report in 2021 in Afghanistan for men, women, and the average of both sexes were 53.4, 54.4, and 53.9 years. RF is the cancer risk factor per Sievert of ionizing radiation received, which is considered equal to 0.05 according to the recommendation of the International Committee on Radiological Protection (ICRP).

$$ELCR = 0.93016 * 10^{-3}\left(\frac{\text{sv}}{\text{year}}\right) \times 59.9(years) \times 0.05\left(\frac{1}{\text{sv}}\right)$$
$$= 2.7858292 \times 10^{-3}$$

Results

The average and standard deviation of the amount of gamma radiation from environmental radiation in Kabul city on one day at different seasons in open and closed spaces are listed in Table 1. As can be seen, the highest dose in open and closed spaces was on date 2024/6/29 with values of 1.3491±0.210 and 1.5148±0.325, respectively, while the lowest dose was in open spaces with values of 1.2122±0.086 and closed spaces with values of 1.4411±0.210, although these values were not statistically significantly different from each other. These values result in annual effective doses of 1.037162 and 0.864724 on dates 29/06/2024 and 30/10/2024, respectively.

Table 2 shows the mean and standard deviation of gamma-ray dose in open and closed spaces and the annual effective dose in 6 geographical areas of Kabul city. The highest dose for the total date of 2024/6/29 of the year was related to the 15th district of Kabul city, 1.782±0.101 mSv/year in open space and 2.0495±0.131 mSv/year in closed space. The lowest dose of 1.005±0.47 millisieverts/year in open space in the Third District. 1.1080 ∓ 0.002 millisieverts/year in the closed space belongs to the Sixth District of Kabul city. These values result in annual effective doses of 1.3972 and 0.785708 millisieverts per year for residents of District 3 of Kabul, respectively. The average annual dose of natural gamma radiation in Kabul city was 1.292±0.163 and 1.4046±0.219 mSv/year, respectively. These values result in an annual effective dose from open and closed spaces of 0.18088 and 0.74928 millisieverts and an annual effective dose of 0.93016 millisieverts for residents of Kabul. Considering the annual effective dose, the excess lifetime risk of cancer from naturally occurring gamma radiation for residents of Kabul was found to be 2.7858292×10^{-3} .

Discussion

In many countries around the world, studies related to the measurement of environmental radiation are of great importance[16, 17]. Numerous studies have reported the levels of radiation from natural sources to assess the annual effective dose in communities. Some of these studies have been conducted only in open environments, others in enclosed spaces, and some in both. In a study conducted by Ahmed and colleagues in Baghdad, the average background gamma dose rate in open and enclosed environments and the annual effective dose were reported to be 121 ± 22 and 111 ± 24 mSv/h, and 0.729 mSv, respectively, indicating lower values compared to the present study [1]. In another study conducted in Costa Rica, the average background gamma dose rate in open and enclosed environments was reported to be 82 and 121 nSv/h, respectively, and the annual effective dose was found to be 0.74 mSv, indicating lower values compared to the present study[16].

Table 1: Mean and standard deviations of open and closed gamma dose and annual effective dose during 2024 in Kabul city.

Date	$\overline{\mathbf{D}_{out}}\left(\frac{mS}{Year}\right)$	$\overline{\mathbf{D}_{in}}\left(\frac{mS}{Year}\right)$	$\mathbf{AED_{out}}\ (ms)$	$\mathbf{AED_{in}}\ (ms)$	$\mathbf{AED_{Total}}\ (ms)$
2024/3/28	1.3147±0.186	1.2579±0.132	0.184058	0.704424	0.888482
2024/6/29	1.3491±0.210	1.5148 ± 0.325	0.188874	0.848288	1.037162
2024/10/30	1.2122±0.086	1.4411±0.210	0.169708	0.٨٠٧٠١٦	0.864724
Average	1.292±0.163	1.4046 ±0.219	0.18088	0.74928	0.93016

Table 2: Average and standard deviation of open and closed gamma dose and annual effective dose during 2024 in Kabul city.

Districts	$\overline{\mathbf{D}_{out}}\left(\frac{mS}{Year}\right)$	$\overline{\mathbf{D}_{in}}\left(\frac{mS}{Year}\right)$	$\mathbf{AED_{out}}\ (ms)$	$\mathbf{AED_{in}}\ (ms)$	$\mathbf{AED_{Total}}\ (ms)$
Third District	1.005 ± 0.47	1.1518 ± 0.۰۵۶	0.1407	0.645008	0.785708
Fifth District	1.0849 ± 0.014	1.1396 ± 0.007	0.151886	0.607533	0.790062
Sixth District	1.0512 ± 0.005	1.1080 ± 0.002	0.147168	0.638176	0.767648
Tenth District	1.035 ± 0.003	1.1203 ± 0.002	0.14419	0.627368	0.772268
Eleventh District	1.6985 ± 0.203	1.8584 ± 0.236	0.23779	1.040704	1.278494
Fifteenth District	1.782 ± 0.101	2.0495 ± 0.131	0.24948	1.14772	1.3972
An average of Six Districts	1.292 ± 0.163	1.4046 ± 0.219	0.18088	0.74928	0.93016

Table 3: Total annual effective dose and excess risk of cancer due to radiation during 2024 in Kabul city.

Districts	$\mathbf{AED_{Total}}\ (ms)$	ELCR
Third District	0.785708	2.35319546× 10^{-3}
Fifth District	0.916062	2,74360569× 10^{-3}
Sixth District	0.767648	2.29910576 × 10^{-3}
Tenth District	0.772268	٢.312933675 × 10^{-3}
Eleventh District	1.278583	3.829356085 × 10^{-3}
Fifteenth District	1.3972	4. 184614 × 10^{-3}
Kabul city	0.93016	2.٧٨٥٨٢٩٢ × 10^{-3}

In the present study, the values in Kabul City were 147.488, 160.3424 nSv/h, and 0.93016 mSv, respectively. These values are higher compared to the results of Boozar Jamahri and colleagues, who reported 122 ± 6.8 and 110 ± 7.4 nSv/h, and an annual effective dose of 0.72 mSv in Yazd Province[9]. Gholami and colleagues reported average gamma dose rates of 119 ± 27 nSv/h in open environments and 113 ± 26 nSv/h in enclosed environments, with an annual effective dose of 0.72 mSv in Lorestan Province[12]. Saghatchi and colleagues reported average gamma dose rates of 135 ± 23 nSv/h in open environments and 127 ± 20 nSv/h in enclosed environments, with an annual effective dose of 0.82 mSv in Zanjan Province[19]. Bahreini Toosi and colleagues reported average gamma dose rates of 138 ± 20 nSv/h in open environments and 115 ± 15 nSv/h in enclosed environments, with an annual effective dose of 0.80 mSv in Kurdistan Province[5]. Bahreini Toosi and ± 42 nSv/h in outdoor environments and 92 ± 36 nSv/h in indoor environments, with an annual effective dose of 0.72 mSv in Kerman[6]. Basir Jafari and colleagues reported an average outdoor gamma dose rate of 94 ± 24 nSv/h in Gilan[8]. Bahreini Toosi and colleagues reported gamma dose rates of 147 nSv/h in outdoor environments and 114 nSv/h in indoor environments, with an annual effective dose of 0.86 mSv in Tabriz[3].

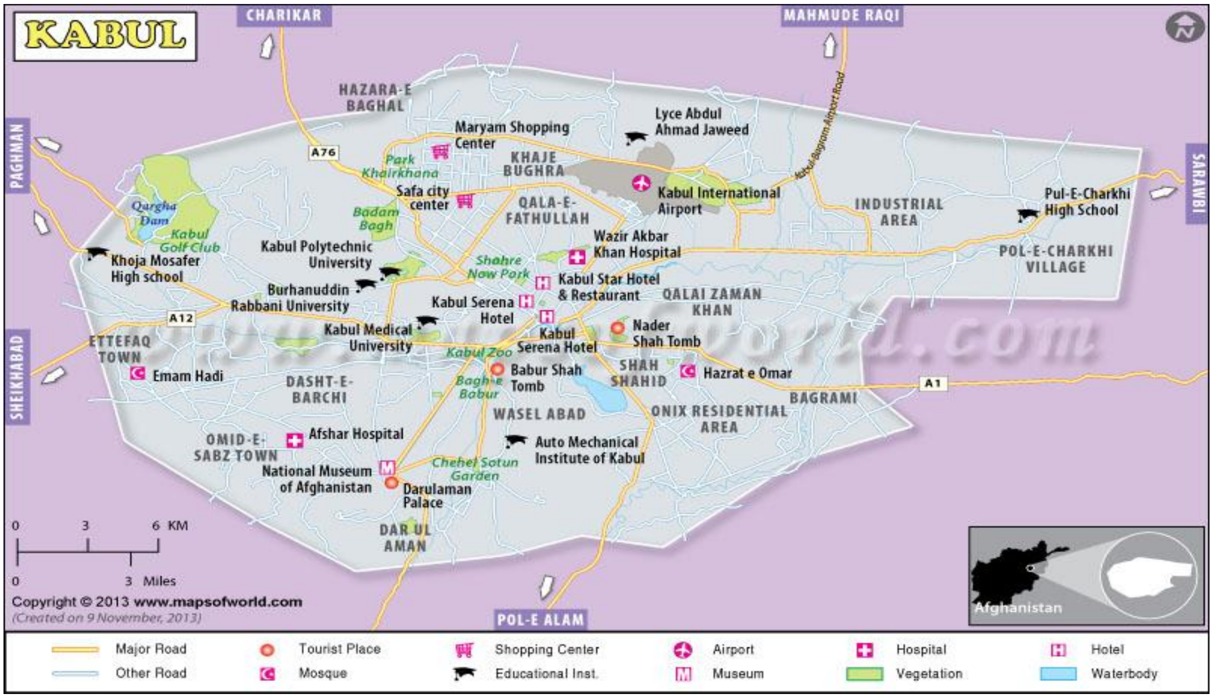
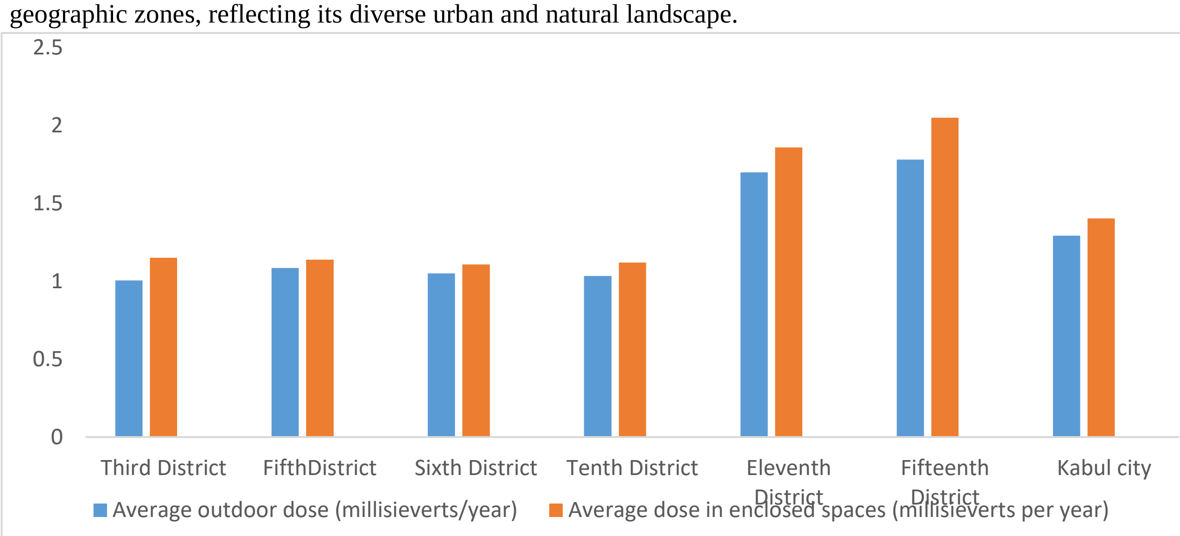


Figure 1: Based on the map of Kabul City, gamma radiation was measured at various points across six geographic zones, reflecting its diverse urban and natural landscape.



Bahreir

Figure 2: Comparison of background gamma dose rates in open and closed spaces in Kabul city

outdoor environments and 114 nGy/h in indoor environments, with an annual effective dose of 0.89 mSv in Urmia[7]. The comparison indicates that

The Annual effective dose received by residents in Kabul City is higher than that in most of the aforementioned cities. The comparison of the average gamma dose rate in open and enclosed environments and the annual effective dose On the other hand, the results of Hazrati and colleagues, with gamma dose rates of 277 and 284 nSv/h and an annual effective dose of 1.73 mSv in Ardabil Province[14] indicate higher annual effective dose values in their study compared to the present study.

Additionally, the study conducted by Jafarpoor and his colleagues shows that the annual effective dose and the associated lifetime cancer risk were calculated to be 1.10 mSv and 4.14×10^{-3}, respectively, indicating higher levels of both annual effective dose and cancer risk compared to the present study[15].

Similar studies in other countries indicate that the annual effective dose from background radiation in Canada is 65 millisieverts per year .Similarly, the annual effective dose in the city of Urmia was reported as 0.9

millisieverts per year[23]. The results are consistent with the findings of the study on environmental radiation levels in open and closed spaces in Kabul during different days of the seasons, and similar results have been obtained.

The global average annual effective dose is reported to be 0.48 millisieverts per year, and the average cancer risk associated with this dose The outdoor dose rate depends on factors such as altitude above sea level, geographical latitude, and the type of soil and rock in the region, among which the composition of soil and rock is of greater importance. Therefore, the high average outdoor dose rate in Kabul city can be justified based on the above-mentioned factors. Moreover, the elevated average indoor gamma dose rate is related to the same soil in those areas and the type of stone used as the main construction material.

Conclusion

The analysis of gamma radiation levels in Kabul City demonstrates a significant elevation in the annual effective dose and the associated excess lifetime cancer risk when compared to globally accepted baseline values. This discrepancy is likely influenced by a combination of factors, including the natural abundance of radionuclides in local geological formations, unregulated urban expansion lacking radiological assessments, and the absence of adequate public health policies or awareness regarding radiation safety. These results underscore the urgent need for comprehensive environmental radiation monitoring systems, public education initiatives, and the development of regulatory frameworks aimed at reducing long-term exposure risks for the local population.

Acknowledgments

The researchers express their gratitude to the esteemed Directorate of Scientific Research of Kabul University of Medical Sciences (KUMS) and all individuals who, in any way, assisted in the execution of this research.

Conflict of Interest

The authors declare that there is no scientific, financial, or personal conflict of interest that could have influenced the conduct of this research or the writing of this article. This study was conducted independently, and no institution or organization was involved in the data analysis or manuscript preparation.

over a lifetime is 1.45×10^{-3} [16, 5]. In the present study, the annual effective dose and the cancer risk associated with this dose are calculated to be 0.93016, which are 1937 and 2.0591925517 times higher than the global average.

References

1. Ahmed RK. Measurement of the average gamma radiation rate for some regions in Baghdad city. Journal of Kufa. Physics. 2012 Jul 1; 4.
2. Ansari SM. General geography of the provinces of Afghanistan.
3. Bahreyni Tossi MT. Evaluation of environmental gamma radiation level in the Azerbaijan area. IJBMS. 2000; 3(1):1-7.
4. Bahreyni ts, yarahmadi m. Evaluation of annual effective dose and equivalent dose of sensitive organs of the general population in Kurdistan province, arising from environmental gamma radiation.
5. Bahreyni MT, Yarahmadi M. Comparison of indoor and outdoor dose rates from environmental gamma radiation in Kurdistan province. Journal of Kerman University of Medical Sciences. 2009 Jul 1; 16(3):255-62.
6. BAHREYNI TS, Jomehzadeh A. Comparison of environmental gamma radiation of Kerman province and indoor gamma dose rate in Kerman city using thermoluminescent dosimeter (TLD) and RDS-110.
7. BAHREYNI TS, Bayani SH, Yarahmadi M, Aghamir A, Jomehzadeh A, Haghparast M, Tamjidi A. Gonad, bone marrow and effective dose to the population of more than 90 towns and cities of Iran, arising from environmental gamma radiation.
8. Basirjafari S, Aghayari S, Poorabas SM, Moladoust H, Asadinezhad M. Assessment of outdoor gamma radiation dose rates in 49 cities of Guilan Province, Iran. Iranian Journal of Medical Physics. 2014 Mar 1; 11(1):168-74.
9. BOUZARJOMEHRI F, Ehrampoush MH. Gamma background radiation in Yazd province: a preliminary report.
10. Eslami A, Shahsavani A, Saghi MH, Akhoondi L, Goorani A. Outdoor gamma radiation measurement in order to estimate the annual effective dose and excess lifetime cancer risk for residents of Tehran, Iran. Journal of Air Pollution and Health. 2016;1(4):243-50.
11. Ghiassi-Nejad M, Mortazavi SM, Cameron JR, Niroomand-Rad A, Karam PA. Very high background radiation areas of Ramsar, Iran: preliminary biological studies. Health physics. 2002 Jan 1; 82(1):87-93.
12. Gholami M, Mirzaei S, Jomehzadeh A. Gamma background radiation measurement in Lorestan province, Iran.
13. Hall EJ, Giaccia AJ. Fractionated radiation and the dose-rate effect. Radiobiology for the Radiologist. 2012:67-85.
14. Hazrati S, Baghi AN, Sadeghi H, Barak M, Zivari S, Rahimzadeh S. Investigation of natural effective gamma dose rates case study: Ardebil Province in Iran. Iranian journal of environmental health science & engineering. 2012 Dec; 9:1-6.
15. Jafarpour SM, Aliasgharzade A, Moradi H, Mohseni M. Measurement of outdoor and indoor natural gamma background radiation and risk of cancer in residents of Kashan during 2016-2017. Feyz Medical Sciences Journal. 2018 Oct 10; 22(5):525-31.
16. Mora P. Outdoor and indoor dose assessment using environmental thermoluminescence dosimeters (TLDs) in Costa Rica. Journal of Radiological Protection. 2003 Dec 8; 23(4):431.
17. Tomás Zerquera J, Perez Sanchez D, Prendes Alonso M, Brígido Flores O, Hernández Pérez A. Study on external exposure doses received by the Cuban population from environmental radiation sources. Radiation protection dosimetry. 2001 May 1; 95(1):49-52.
18. Rostampour N, Almasi T, Rostampour M, Mohammadi M, Ghazikhanlou Sani K, Khosravi HR, Pooya SM, Golzar B, Jabari Vesal N. An investigation of gamma background radiation in Hamadan province, Iran. Radiation protection dosimetry. 2012 Dec 1; 152(4):438-43.
19. Saghatchi F, Salouti M, Eslami A. Assessment of annual effective dose due to natural gamma radiation in Zanjan (Iran). Radiation protection dosimetry. 2008 Dec 1; 132(3):346-9.
20. Schauer DA, Linton OW. The National Council on Radiation Protection and Measurements report shows a substantial medical exposure. Radiology. 2009 Nov; 253(2):293-6.
21. Streffer C. The ICRP 2007 recommendations. Radiation protection dosimetry. 2007 Nov 1; 127(1-4):2-7.
22. Streffer C. The ICRP 2007 recommendations. Radiation protection dosimetry. 2007 Nov 1; 127(1-4):2-7.
23. Annex D, United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. Investigation of I. 2000; 125.
24. Ishikawa T. Radiation doses and associated risk from the Fukushima nuclear accident: a review of recent publications. Asia Pacific Journal of Public Health. 2017 Mar; 29(2_suppl):18S-28S.