Environ Geochem Health
https://doi.org/10.1007/s10653-019-00300-y

ORIGINAL PAPER

Estimate the effective dose of gamma radiation in Iran cities: lifetime cancer risk by Monte Carlo simulation model

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Received: 7 January 2019 / Accepted: 20 April 2019

Abstract Background radiation can be different in both indoor and outdoor places. Background radiation is always in the environment, and all people in the community are constantly exposed to it. The most important source of exposure to gamma ray is natural radionuclides. Gamma rays can have harmful effects on the human body. The purpose of this study was to evaluate the health risk of gamma-ray exposure and to simulate using the Monte Carlo simulation. In this study, gamma-ray data were extracted from the studies carried out at intervals January 1, 2000, to December 31, 2018. Iranian and international databases were used to search for the articles. A total of 11 studies were found. To determine the health effects of gamma-ray radiation, the annual effective dose and excess lifetime cancer risk were calculated. To determine the uncertainty, a health risk assessment was conducted via Monte Carlo simulation. In outdoor, the mean, highest, and lowest absorbed dose of gamma ray were 117.82 nSv/h, 295.17 nSv/h, and 49 nSv/h, respectively. Ardabil Province and Chaharmahal and Bakhtiari Province have the highest and lowest gamma ray concentrations, respectively. In indoor, the mean, highest, and lowest absorbed dose of gamma ray were 118.22 nSv/h, 141 nSv/h, and 60.2 nSv/h, respectively. The last column, the mean, maximum, and minimum of excess lifetime cancer risk values for gamma-ray radiation were 2.45E−3, 4.17E−3, and 4.61E−4, respectively.

Keywords Background radiation · Gamma ray · Monte Carlo simulation · ELCR · Iran

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Published online: 06 May 2019

Introduction

A human being has always been exposed to ionizing radiations. These radiations come from a variety of sources (Bahreyni Toossi and Yarahmadi 2009; Kahani et al. 2016). The ionizing radiation that is always exposed to humans and other creatures is called background radiation. The existence of any obstacle to the emission of radiation can ultimately affect the extent of background radiation. Accordingly, background radiation can be different in both indoor and outdoor places (Asere and Ajayi 2017; Bouzarjomehri and Ehrampoush 2005). The main sources of outdoor radiation are two cosmic and terrestrial sources (Gholami et al. 2011; Moeller and Sun 2006). In the evaluation of the amount of exposure in indoor places, two important points should be considered. First, building materials are a protective shield against cosmic and terrestrial radiation. Second, these construction materials themselves, depending on its type, can be a source of radiation and ultimately increase effective absorbed dose rate (Basirjafari et al. 2014; Ramli et al. 2005). Given that most people spend close to 80% of their time in closed places, estimates of absorbed dose rates from these environments are also important. There are several studies that reported radiation from construction materials (Iyogi et al. 2002; Mjönes 1986; Tavakoli 2003). Environmental gamma rays are in fact rays from the decay of natural radioactive sources of uranium and thorium that pollute environmental resources around them (Eslami et al. 2016). Background radiation is always in the environment, and all people in the community are constantly exposed to it. Gamma rays are high-energy electromagnetic beams which are released from the nucleus and are like X-rays, but shorter wavelengths and more energy from them (Almgren 2008; Eslami et al. 2016). Gamma rays are ionized and therefore harmful to human health. Gamma rays are located at the end of the spectrum and above the X-ray area. Gamma ray is a kind of electromagnetic waves. Its atomic mass is negligible and lacks an electric charge. Its speed is equal to the speed of light, and its wavelength varies from 1 to 0.1 Å. Gamma ray is a high-energy radiation. The energy of gamma photons is 10,000 times the energy of visible-light photons in the electromagnetic spectrum. Accordingly, gamma photons may travel hundreds and thousands of meters in the air until they lose all their energy (Almgren 2008). Gamma-ray energy varies from 10 keV to 10 mega-electron volts (MeV). The most important source of exposure to gamma ray is natural radionuclides, especially potassium 40 in soil and food (Eslami et al. 2016). Rays released by the body deal with the energy itself, and this energy can destroy the tissue. Gamma-ray radiation has various effects, such as physical, chemical, and biological. Biological effects of gamma ray include skin redness due to prolonged radiation, ulcers, or complete destruction of body tissues due to continuous exposure to radiation and skin or blood cancers due to extremely long exposures with relatively low levels. Gamma-ray radiation can have harmful effects on the human body, such as shortening life, reducing body resistance, reducing reproductive capacity, creating cataracts, causing leukemia and damage to the fetus, teratogen, and mutagen (Eslami et al. 2016; Taskin et al. 2009). Changed cells may produce abnormal cells during proliferation. In other words, radiation causes ionization in living cell molecules. This ionization leads to the release of electrons from atoms and the formation of ions or pregnant atoms. Finally, these ions react with other atoms, creating health risks for cells. If gamma-ray radiation passes through the cell, ionizing molecular water near DNA will eventually cause ions to react with it and break its chain (Bouzarjomehri and Ehrampoush 2005; Eslami et al. 2016; Tavakoli 2003). According to the latest data provided by the United Nations Scientific Committee (UNSC) on the effects of atomic beams, the average global radiation of each individual is 2.4 millisievert (mSv). Of this amount, 1.1 mSv is related to gamma rays from the cosmic rays and radiation sources in the Earth's crust. The average global effective dose, also, due to gamma rays in the soil due to outdoor radiation is 0.5 mSv (Eslami et al. 2016). Based on what has been said, the purpose of this study was to evaluate the health risk of gamma-ray exposure and to simulate these effects using the Monte Carlo simulation. One of the main disadvantages of the previous studies in Iran which measured gamma radiation was that it was not considered the annual effective dose and excess lifetime cancer risk. In this study, based on previous studies, these cases were calculated and the Monte Carlo simulation was used to remove uncertainties in the spot estimations.

Materials and methods

Study area

The Islamic Republic of Iran is one of the largest countries in the Middle East. According to the latest divisions, the country has 31 provinces. At present, Iran has a population of 81 million. The area of Iran is 100 square kilometers.

Search strategy

In this study, gamma-ray data were extracted from original articles published at intervals January 1, 2000, to December 31, 2018. International and Iranian databases such as Google Scholar, Web of Science, Science Direct, PubMed, Scopus, Irandoc, Magiran, Scientific Information Database (SID), and Information Institute for Scientific (ISC) were investigated for this purpose. Used keywords (or screening keywords) consist of "Ray, Gamma," "Rays, Gamma," "Radiation, Gamma," "Gamma Radiation," "Gamma Radiations," "Radiations, Gamma," "natural radiation," "Iran," and combined or alone together with "OR" and/or "AND" in title, abstract, keyword, and all fields. After the initial search, articles were investigated for their eligibility to be included in the study. Finally, the essential data were obtained through the selected articles and inserted into file for further analysis.

Inclusion criteria and data extraction

In the current study, inclusion criteria were: reporting of gamma radiation in indoor and outdoor air; cross-sectional study; published in English language and reporting of effective dose and study performed in Iran. Also, books, review articles, and experimental studies were excluded. Extracted characteristics of each study consist of the location of study, the location of sampling (indoor and outdoor), and effective dose values. Finally, 11 studies were selected. In this work, for each of the 11 final papers according to the obtained mean, standard deviation, maximum, minimum, year of study, and location were calculated in the separate articles using the MS Excel. Information about these studies is shown in Table 1. With a preliminary review, it appears which has spread to almost the whole country (11 provinces of Iran). Figure 1 shows the provinces where gamma-ray radiation is measured.

Health risk assessment

The probability of cancer risk to any population from exposure to gamma-ray radiation in the different research is a measure of the excess lifetime cancer risk (ELCR). It was calculated based on the estimated annual effective dose using the equations in MS Excel 2013 (Kolo et al. 2017). Using Eq. 1, the annual effective dose of residents of Iran, which is due to the natural radiation of cosmic rays and radiation from radioactive substances in the Earth's crust, was calculated (Monica et al. 2016; Sharma et al. 2014):

$$\mathrm{AED(Sv)} = C(0.2D_{\mathrm{out}} + 0.8D_{\mathrm{in}}) * T, \tag{1}$$

where AED is an average effective dose. C is a conversion factor of absorbed dose (Gy) to the effective dose (Sv). The value of C is 0.7. D_{out} and D_{in} are outdoor absorbed dose rate and indoor absorbed dose rate, respectively. The constant value of 0.2 and 0.8 is the occupancy factor, OF, for the outdoor and indoor exposure, respectively. T is the conversion factor of the hour to a year. In the next step, excess lifetime cancer risk, ELCR, was calculated according to Eq. 2 (Kahani et al. 2016; Sharma et al. 2014):

$$\mathrm{ELCR} = \mathrm{AED} * \mathrm{DL} * \mathrm{RF}, \tag{2}$$

where AED is the annual effective dose. DL is the duration of life (almost 70 years). RF is a risk factor (1/Sv) which is a fatal cancer risk per sievert. The value of RF for public exposure is 0.056, based on ICRP 60 (Asere and Ajayi 2017).

Monte Carlo simulation

Health risk assessment is a complex process because many factors must be taken into consideration (Qu et al. 2012). In typical methods of health risk assessment, the risk value is reported as spot estimation. The spot estimates if health risk provides little information about the degree of uncertainty surrounding the risk point (Mesdaghinia et al. 2016). Factors affecting uncertainty include (1) parameter uncertainty, (2) model uncertainty, and (3) scenario uncertainty (Koupaie and Eskicioglu 2015). If these

Table 1 General data of 11 studies included in this study

Study	Location	Location	Gamma (nSv/h)				References
			Mean	Min	Max	SD	
Bahreyani and Sadeghzade (2000)	Azerbaijan	Outdoor	153.67	66	260	–	Bahreyni and Sadeghzade (2000)
Hazrati et al. (2012)	Ardabil	Outdoor	290.72	219	358	–	Hazrati et al. (2012)
Pashazadeh et al. (2014)	Bushehr	Outdoor	51.8	–	–	8.8	Pashazadeh et al. (2014)
		Indoor	60.2	–	–	7.2	
Shahbazi–Gahrouei (2003)	Chaharmahal and Bakhtiari	Outdoor	49	–	–	–	Shahbazi-Gahrouei (2003)
Saghatchi et al. (2008)	Zanjan	Outdoor	127	–	–	20	Saghatchi et al. (2008)
		Indoor	135	–	–	23	
Eslami et al. (2016)	Sabzevar	Outdoor	123	66	178	24	Eslami et al. (2016)
		Indoor	141	–	–	–	
Bahreyani Tosi and Yarahmadi (2009)	Kurdistan	Outdoor	111	–	–	11	Bahreyni Toossi and Yarahmadi (2009)
		Indoor	138.13	–	–	11.87	
Bahreyni and Jomehzadeh (2005)	Kerman	Outdoor	93.66	0.61	1.032	0.31	Bahreyni and Jomehzadeh (2005)
Basirjafari et al. (2014)	Guilan	Outdoor	95.33	65	127	–	Basirjafari et al. (2014)
Gholami et al. (2011)	Lorestan	Outdoor	114.67	65	166	26	Gholami et al. (2011)
		Indoor	116.67	74	157	27	
Bouzarjomehri and Ehrampoush (2005)	Yazd	Outdoor	101.4	–	–	7.4	Bouzarjomehri and Ehrampoush (2005)
		Indoor	122	–	–	6.8	

uncertainties are ignored, the accuracy of the data obtained is heavily influenced and that will not be appropriately accurate (Shahrbabki et al. 2018). To address this issue, the United States Environmental Protection Agency (USEPA) recommends using Monte Carlo simulated (MCS) procedure (Kumar and Xagoraraki 2010; Rajasekhar et al. 2018). Therefore, MCS procedure usually deals with the factors affecting uncertainties. In this way, the probabilistic statistics is used to determine the uncertainty of each effective parameter. So, MCS procedure presents better health risk identification and exposure evaluation or assessment (Mesdaghinia et al. 2016; Miri et al. 2018). In this procedure, the main parameters distribution is inserted into exposure equation (randomly) and the process achieved many times, until the distribution of predicted results, which indicate overall uncertainty of input parameters, is obtained (Jiang et al. 2015; Miri et al. 2018; Saha et al. 2017). Table 2 presents input variables of health risk assessment model simulated by Monte Carlo technique. The Oracle Crystal Ball software (version 11.1.2.4.600, Build 11.1.4512.0 on 1/11/2016) was used to perform Monte Carlo simulation calculations. This software is added to the MS Excel 2013 software as “Add-ins.”

Results and discussion

Gamma radiation dose

Gamma-ray radiations from terrestrial radionuclides depend on soil type, geological composition, and the conditions of area geographic, while the amount of radiation received from the environmental cosmic rays is more dependent on altitude and latitude of the location (Kahani et al. 2016). The average absorbed dose of gamma ray measured in different cities of Iran is shown in Table 1. Of course, in some studies on outdoor, indoor or both places has been reported. According to Table 1, the mean gamma-ray radiation, outdoor, in the studied provinces in Iran is 117.82 nSv/h. Also, the highest and lowest gamma-ray radiations were 295.17 nSv/h and 49 nSv/h, respectively. Ardabil

Fig. 1 Distribution of gamma radiation measurement studies

Table 2 Input variables of health risk assessment model simulated by Monte Carlo technique

Parameters	Symbol	Unit	Distribution type	Value
Conversion factor	C	–	Fixed value	0.7
Outdoor absorbed dose rate	D_{out}	nSv/h	Triangular and normal	–
Indoor absorbed dose rate	D_{in}	nSv/h	Triangular and normal	–
Occupancy factor	OF	–	Fixed value	0.2 and 0.8
Conversion factor	T	hour to a year	Fixed value	8760
Duration of life	DL	years	Fixed value	70
Risk factor	RF	1/Sv	Fixed value	0.056

Province and Chaharmahal and Bakhtiari Province have the highest and lowest gamma-ray radiation, respectively. In Ardabil, average absorbed dose for the cities of Ardabil, Sar-Ein, Germy, Neer, Shourabil Recreational Lake, and Kosar was 265 nSv/h, 219 nSv/h, 344 nSv/h, 233 nSv/h, 352 nSv/h, and 358 nSv/h, respectively (Hazrati et al. 2012). Some studies show that altitude in all of these cities is almost the same, and the main reason for the difference in gamma-ray radiation can be due to the difference in the soil type of the area. The two cities such as Kosar and Germy which have the highest absorbed dose are located in a rocky area. Therefore, altitude plays an important role in the rate of background radiation, especially gamma-ray radiation. Some studies show that the highest gamma-ray radiation is associated with places comprising metamorphic rocks heavily intruded by granite rock and granitic pegmatites. One of the main causes of natural irradiation is the presence of radionuclides in the Earth's crust (K-40, U-238, and Th-232 and their decay products) (Asere and Ajayi 2017). The contents of natural radionuclides and the thin layer of atmosphere in the higher altitude regions (mountains) are reasons why they have high levels of human exposure (Shahbazi-Gahrouei 2003). Of course, this is not a general rule. The Shahrekord in the province of Chaharmahal and Bakhtiari is known as the roof of Iran and has the highest altitude. The results of the study, by Shahbazi-Gahrouei (2003), indicated that gamma-ray radiation in Shahrekord was least among the studied provinces. In other words, in some places like Shahrekord, although they are high altitude, their natural irradiation rates were low. One of the reasons for this low level of natural irradiation can be the low concentrations of radionuclides in the soil (Saghatchi et al. 2008; Shahbazi-Gahrouei 2003). According to Saghatchi et al. 2008, there are two reasons for high gamma radiation: (1) magmatic areas in the north part of the Zanjan and (2) the presence of granite rock and granodioritic mines in Tarom Mountain (name of a mountain in around Zanjan). Some locations in the northern parts of the Zanjan, like Gilvan and Darram, in Tarom area, indicated relatively high gamma-ray radiation despite their low altitude (Saghatchi et al. 2008). In Asere and Ajayi (2017) study, the highest gamma-ray radiation was measured in Ifira Akoko with a mean of 0.12 μSv/h corresponding to an annual effective dose of 0.21 mSv/y. This research showed that the study area contains a lot of uranium-rich granite gneiss rocks (Asere and Ajayi 2017). Based on Table 1, the mean absorbed dose of gamma-ray radiation, indoor, in the studied provinces is 118.22 nSv/h. Also, the highest and lowest gamma-ray radiations were 141 nSv/h and 60.2 nSv/h, respectively. The provinces which have the highest and lowest gamma-ray radiation were Sabzevar and Bushehr, respectively. The amount of gamma-ray radiation in the indoor place is more dependent on the material used in building the house. Eslami et al. 2016 in the northwest of Iran, Sabzewar, reported that the indoor-to-outdoor radiation ratio was 1.12. This ratio in the world is on average 1.4 (Eslami et al. 2016). High dose of gamma-ray radiation has been reported in countries such as China, Albania, Malaysia, Portugal, Hungary, and Australia. One of the reasons for this high dose of gamma-ray radiation in indoor places can be the high use of masonry or stone materials in building materials (Radiation 2000; Saghatchi et al. 2008). Asgharizadeh et al. 2011 investigated the activity radionuclide concentration of K-40, Ra-226, and Th-232 in various commercial granite stones used as building materials in Iran. The results showed that the activity radionuclide concentration of K-40, Ra-226, and Th-232 was 556-1539 Bq/kg, 6–160 Bq/kg, and 18–178 Bq/kg, respectively. Also, the average radionuclide concentration of K-40, Ra-226, and Th-232 was 1193 Bq/kg, 72 Bq/kg, and 76 Bq/kg, respectively. Based on the National Council on Radiation Protection (NCRP), global estimated values of K, Th, and Ra in granite rock as building material are 1184 Bq/kg, 8 Bq/kg, and 63 Bq/kg, respectively (Asgharizadeh et al. 2011).

Health risk assessment

Table 3 shows the effective annual dose and excess lifetime cancer risk based on point estimates in the different studies. Also, Table 4 shows uncertainty analysis for the annual effective dose and excess lifetime cancer risk based on the Monte Carlo simulation model. Based on MCS in Table 3, the highest and lowest effective annual dose was 1.0439 mSv, Eslami et al. (2016), and 0.1155 mSv, Bahreyani Tosi et al., respectively. The annual effective dose was calculated according to Eq. 1 (Sharma et al. 2014). Figure 2 shows the comparison of the annual effective dose of gamma-ray radiation in Iran and the average of the annual effective dose in the

Table 3 Effective annual dose and excess lifetime cancer risk based on point estimates in the different studies

Study	Location	Place	Mean gamma (nSv/h)	SD (nSv/h)	Annual effective dose (E, mSv)	Excess lifetime cancer risk (ELCR)
Bahreyani and Sadeghzade (2000)	Azarbayjan	Outdoor	135	40.10	0.1656	6.61E−04
Hazrati et al. (2012)	Ardabil	Outdoor	295.17	28.42	0.362	1.44E−03
Pashazadeh et al. (2014)	Bushehr	Outdoor	51.8	8.80	0.3588	1.43E−03
		Indoor	60.2	7.20		
Shahbazi–Gahrouei (2003)	Chaharmahal and Bakhtiari	Outdoor	49	4.90	0.0601	2.40E−04
Saghatchi et al. (2008)	Zanjan	Outdoor	127	20	0.8181	3.26E−03
		Indoor	135	23		
Eslami et al. (2016)	Sabzevar	Outdoor	125	22.87	0.845	3.37E−03
		Indoor	141	14.10		
Bahreyani Tosi and Yarahmadi (2009)	Kurdistan	Outdoor	111	11	0.8137	3.25E−03
		Indoor	138.125	11.87		
Bahreyni and Jomehzadeh (2005)	Kerman	Outdoor	93.66	9.83	0.1149	4.58E−04
Basirjafari et al. (2014)	Guilan	Outdoor	94	12.66	0.1153	4.60E−04
Gholami et al. (2011)	Lorestan	Outdoor	113	20.62	0.7224	2.88E−03
		Indoor	119	16.96		
Bouzarjomehri and Ehrampoush (2005)	Yazd	Outdoor	101.4	7.40	0.7229	2.88E−03
		Indoor	122	6.80		

world. In some parts of Iran, like Azerbaijan, Ardabil, Bushehr, Chaharmahal and Bakhtiari, Kerman, and Guilan, the annual effective dose is less than the global average. Also, in the provinces of Zanjan, Sabzewar, Kurdistan, Lorestan, and Yazd, the annual effective dose is higher than the global average. The global average of the annual effective dose is 0.5 mSv (Eslami et al. 2016; Saghatchi et al. 2008). Based on Table 2, the last column, the mean, maximum, and minimum of ELCR values for gamma-ray radiation were 2.45E−3, 4.17E−3, and 4.61E−4, respectively. According to the previous studies, the average global value of ELCR is 2.9E−4 (Asere and Ajayi 2017; Eslami et al. 2016). Figure 3 presents the comparison of the ELCR caused by gamma-ray radiation in Iran with the global average. As shown in Fig. 3, in all studies except Chaharmahal and Bakhtiari, the gamma-ray radiation measured in Iran is higher than the global average (2.9E−4). The highest and lowest amounts of ELCR were in provinces of Sabzewar and Kerman, respectively. Therefore, epidemiological studies are recommended to investigate the likelihood of the prevalence of chronic radiation-related illnesses among residents of this city. Asere and Ajayi (2017) reported that the mean, maximum, and minimum of ELCR values for gamma-ray radiation were 0.525E−3, 0.736E−3, and 0.307E−4, respectively. According to the findings of Asere and Ajayi (2017), the ELCR value was higher than the global average (Asere and Ajayi 2017). Monica et al. 2016 reported that the ELCR in the coastal regions of Kollam District, Kerala, from outdoor ranges from 14.95E−3 to 16.65E−3. In this study, also, the ELCR values measured were higher than the worldwide average (Monica et al. 2016). As mentioned earlier, in the time interval investigated, only 11 provinces have been investigated in terms of gamma-ray radiation. Iran has 31 provinces, in which the gamma radiation measured in 11 provinces is about 35%. In the studied provinces, the annual effective dose (5 provinces) and the ELCR levels (10 provinces) were higher than global averages. Therefore, it is recommended that other provinces should be explored for this purpose and relevant epidemiological studies should be carried out.

Table 4 Uncertainty analysis for the annual effective dose and excess lifetime cancer risk based on the Monte Carlo simulation model

Study	Gamma ray (nSv/h)			Uncertainties analysis					
				AED (mSv)			(ELCR) $\times 10^{-3}$		
	$P^{a}_{5\%}$	$P^{b}_{50\%}$	$P^{c}_{95\%}$	$P_{5\%}$	$P_{50\%}$	$P_{95\%}$	$P_{5\%}$	$P_{50\%}$	$P_{95\%}$
Bahreyani and Sadeghzade (2000)	91.87	149.89	225.18	0.1127	0.1838	0.2762	4.50E−04	7.33E−04	1.10E−03
Hazrati et al. (2012)	242.01	291.76	337.1	0.1127	0.3578	0.4134	1.65E−03	1.43E−03	1.65E−03
Pashazadeh et al. (2014)	37.33	51.8	66.27	0.4347	0.3588	0.4347	1.73E−03	1.43E−03	1.73E−03
	48.36	60.2	72.04						
Shahbazi–Gahrouei (2003)	40.94	49	577.06	0.7077	0.0601	0.7077	2.82E−03	2.40E−04	2.82E−03
Saghatchi et al. (2008)	94.1	127	159.9	1.0439	0.8181	1.0439	4.17E−03	3.26E−03	4.17E−03
	97.17	135	172.83						
Eslami et al. (2016)	84.18	123.4	160.77	1.0027	0.843	1.0027	4.00E−03	3.36E−03	4.00E−03
	117.81	141	164.19						
Bahreyani Tosi and Yarahmadi (2009)	92.91	111	129.26	0.9319	0.8137	0.9319	3.72E−03	3.25E−03	3.72E−03
	118.6	138.13	157.65						
Bahreyni and Jomehzadeh (2005)	77.2	93.66	94.17	0.1155	0.1149	0.1155	4.61E−04	4.58E−04	4.61E−04
Basirjafari et al. (2014)	74.48	95.02	116.89	0.1434	0.1165	0.1434	5.72E−04	4.65E−04	5.72E−04
Gholami et al. (2011)	80.57	114.27	149.64	0.8921	0.7151	0.8921	3.56E−03	2.85E−03	3.56E−03
	87.67	117.21	144.44						
Bouzarjomehri and Ehrampoush (2005)	89.23	101.4	113.57	0.7927	0.7229	0.7927	3.16E−03	2.88E−03	3.16E−03
	110.81	122	133.19						

[a]Percentile 5%

[b]Percentile 50%

[c]Percentile 95%

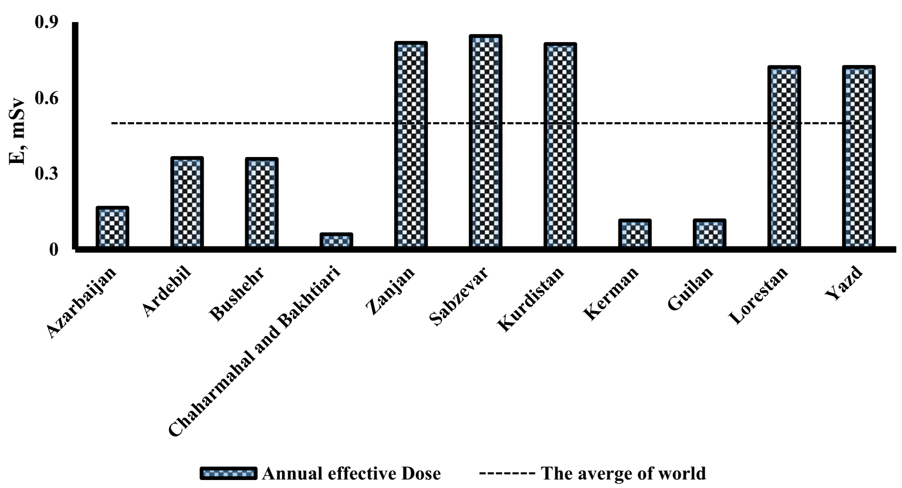

Fig. 2 Comparison of the annual effective dose in Iran with the global average

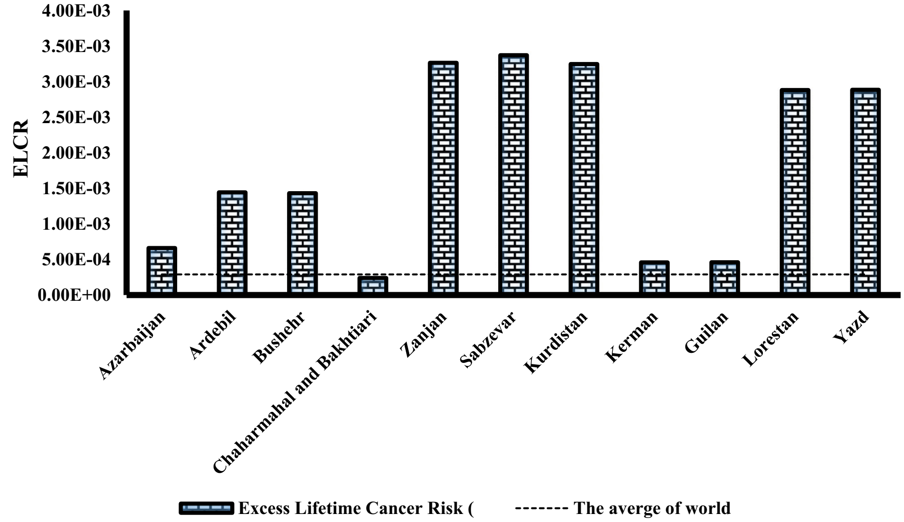

Fig. 3 Comparison of the ELCR caused by gamma ray in Iran with the global average

Conclusion

In this work, gamma-ray data were extracted from studies carried out at intervals 2000 to 2019. International and Iranian databases were used for this review. Finally, 11 studies were found. To determine the health effects of gamma-ray radiation, the annual effective dose and excess lifetime cancer risk were calculated. To determine the uncertainty in this study, the probabilistic statistics was used using Monte Carlo simulation. Iran has 31 provinces, in which the gamma radiation measured in 11 provinces is about 35%. In the studied provinces, the annual effective dose (5 provinces) and ELCR levels (10 provinces) were higher than global averages. The mean gamma ray radiation, outdoor, in the studied provinces in Iran is 117.82 nSv/h. Also, the highest and lowest gamma-ray radiations were 295.17 nSv/h and 49 nSv/h, respectively. Ardabil Province and Chaharmahal and Bakhtiari Province have the highest and lowest gamma-ray radiation, respectively. Therefore, it is recommended that other provinces should be explored for this purpose and relevant epidemiological studies should be carried out.

Acknowledgements The authors of this work thank the Lorestan University of Medical Sciences (LUMS) for supporting this project and the students involved in conducting the experiments.

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