ORIGINAL PAPER

Level of natural radiation in the closed space of the public schools in Hamadan, Iran (2015-2016)

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Date of submission: 29 Dec 2018, *Date of acceptance:* 24 Jun 2020

ABSTRACT

Since human beings are constantly exposed to environmental ionizing radiations, the measurement of natural background radiations is of utmost importance. This cross-sectional, descriptive study aimed to measure the annual effective dose of natural background radiation in 93 schools in two districts of Hamadan, Iran in the winter, spring, and autumn of 2015-2016. Among the public schools in Hamadan, the schools located in district one with 1.41±0.079 mSv and district two with 0.955±0.04 mSv had the highest and lowest mean equivalent annual dose caused by natural radiation (γ rays) in a closed space, respectively. The mean equivalent annual dose caused by natural radiation in the closed space of all the public schools in districts one and two of Hamadan was estimated at 1.20±0.07 mSv as separated by geographical directions. In addition, the highest mean dose caused by natural gamma rays in the closed space of the school buildings constructed for more and less than 40 years was 1.42±0.22 and 1.42±0.15 mSv, respectively, and the rate of the effective annual dose of the public schools in Hamadan was determined to be 0.83 mSv as separated by district. The equivalent effective annual dose and risk of gamma ray cancer in the lifespan of the public school students in Hamadan was higher than the global average.

Keywords: Background radiation, Effective dose, Public schools, Hamadan

Introduction

Since humans are constantly exposed to environmental ionizing rays, the measurement of natural radiation is of the utmost importance.[1] The study of the biological effects of ionizing rays on living organisms has been of interest to scientists for years. Background radiations such as X-rays, betas, and gammas are considered to be the most important ionizing rays found in the form of natural and artificial in nature, as well as in the residence and workplaces of humans.[2]

Although humans often believe that radiation exposure to artificial radioactive sources is harmful, natural radioactive sources play a major role in the radiation exposure of students and living organisms. These sources originate from the earth, and cosmic rays also play a key role in the dose received by students, which could cause damage with variable intensities depending on the concentration of the natural radioactive core in

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Citation: Samadi M T, GolzarKhojasteh B, GolzarKhojasteh M, Khazaei S, Sokhri Mirazizi L. Level of natural radiation in the closed space of the public schools in Hamadan, Iran (2015-2016). J Adv Environ Health Res 2020; 8(4): 281-287

the natural materials in the environment and their application. Therefore, it seems essential to collect data on radioactive natural sources and recognize the influential factors in the exposure of students to radiation, especially in the areas with high natural radioactivity in Iran where the negligence of such sources may cause irreparable human losses, including the partial/complete impairment of physical actions, shortened lifespan, reduced resistance against diseases and reproductive power, cataract, cancer, damage to embryonic growth, destruction of the hematopoietic organs, and adverse effects on the digestive system, brain, genital glands, and skin.[3,4]

According to the latest data published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),[4] the global average of the exposure of each student to total natural radiation sources has been estimated at 2.4 milliseconds per year. In addition, approximately one-third of the total radiation is emitted from external sources, and the remaining two-thirds are emitted from internal sources. The global mean effective dose caused by gamma rays in soil has been reported to be 0.5 mSv.[5] Meanwhile, the mean radiation exposure to all artificial sources, including atomic explosions, nuclear accidents, normal operation of nuclear power plants, and medical radiation of diagnosis and treatment, has been estimated at 0.8 mSv per year.[5]

Gamma rays are high-energy electromagnetic beams emitted from the nucleus, which are similar to X-rays with shorter wavelengths and higher energy than X-rays. Exposure to radiation could increase the risk of cancer.[6] The studies on natural radiation are highly important; in most countries and some provinces in Iran, these radiations have been measured, and their natural radioactivity map has been prepared.[7,8] Furthermore, special attention has been paid to the locations with high background radiation in these areas; such examples are some of the regions in Turkey, India, and Iran.[9-11]

The findings regarding the measurement of the background radiation of natural origin and calculations of the effective annual dose rate could be useful for the risk assessment of additional cancer caused by such radiation in school students, as well as the analysis of the results of cancer-related epidemiological studies. These findings could also indicate the possible changes in environmental radioactivity due to nuclear, industrial, and other human activities.[12]

The present study aimed to determine the annual effective dose rate of the natural background indoor radiation sources in the public school students in Hamadan city, Iran during 2015-2016.

Materials and Methods

This cross-sectional, descriptive study was conducted in the winter, spring, and autumn of 2015-2016. Using the following equation, 93 schools were randomly selected from 600 schools in Hamadan (Fig. 1).

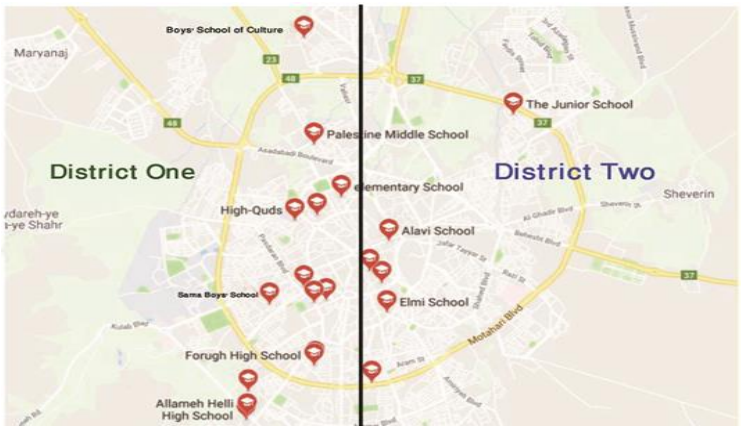

Fig. 1. School location map of Hamadan city

The research instrument was a survey meter (model: RDS-110), which was used for the monitoring of gamma rays. The sensitivity of the device was within the range of 0.05-100 µSv/h; the device has been employed in most of the previous studies in this regard. Prior to the study, the device had been calibrated for two years by the manufacturer (RADOS, Finland).

In each public school (first, second or third floors), the RDS-110 survey meter was placed on a tripod one meter above the ground. Afterwards, 60 counts were recorded for one hour in order to determine the mean dose rate of each school in µSv/h or mSv/h. The measurements were performed in all the selected public schools in different directions, and the mean doses obtained from the public schools of the district in each geographical direction were considered as the mean of the direction. Finally, the mean of different directions was determined and expressed as the mean dose received in the closed space of the public schools as separated by district and the entire city of Hamadan.

In the present study, the dose rate of the natural background radiation in the public schools was initially determined. Based on the study by Rostampour *et al.*[13] and the availability of the dose rate measurement results of natural background radiation (indoor), the annual effective dose of the public school students due to natural light was estimated.

Based on the studies in different districts and schools, the measurements were performed in five school districts in the north, south, west, east, and center of Hamadan city to determine the absorbed dose rate in the closed school environment. According to the latest statistics, the number of the public schools in district one of Hamadan is 350, while it is 250 in district two. The total number of the public schools in districts one and two is 600, and according to the following formula

$$n = \frac{\sum_{h=1}^{H} \frac{N_h^2 S_h^2}{(n_h / n)}}{N^2 \left(\frac{d^2}{Z^2_{\alpha/2}} \right) + \sum_{h=1}^{H} N_h S_h^2}$$

and considering the of the city and buildings at 95% confidence level, the minimum number of the public schools in districts one and two was 48 and 35, respectively. Since each school in the five geographical areas (north, south, east, west, and center) was divided as the number of the metrics in the public schools in district one (290 times), the number of the measurements in the public schools in district two was 175 times. As a result, the total number of the measurements was 465 samples. Notably, the mentioned statistics regarding the number of the public schools in Hamadan city were prepared by the General Directorate of the Education of Hamadan Province.

In the present study, the public schools were categorized in two groups of less than 40 and more than 40 years of construction based on the educational regulations regarding the designation of worn-out buildings, brick concrete, clay, and mud construction materials. According to the report of Hamadan Education Renovation Department, approximately 40% of these school buildings were old and renovated by this department. The number of the buildings that were constructed using materials with less resistance and more pores was higher compared to the newly constructed buildings using materials such as bricks, concrete, cement with block ceilings, and girder; this led to the higher percentage of the cosmic rays passing through the old buildings compared to the new school buildings.

Since the surface layers of Hamadan city are mostly composed of granites and limes in some places, it was attempted to keep the geological status stable as far as possible. The exact points of measurements had to have approximately 30 centimeters of distance from the walls and preferably be away from the doors, windows, cooler channels, and fluorescent lamps.

Statistical analysis

Data analysis was performed in SPSS version 16 to determine the mean natural dose caused by gamma rays in the closed space of the public schools in Hamadan. In order to compare the means, independent t-test and

one-way analysis of variance (ANOVA) were used at 95% confidence coefficient and significance level of P<0.05.

Results and Discussion

Table 1 shows the dosimetry results of the annual natural background dose caused by gamma rays in the closed space of the public schools in Hamadan as separated by district in the winter, spring, and autumn of 2015-2016. According to the results of the present study, the mean range of natural radioactivity in the closed space of the public schools of districts one and two of Hamadan was 0.96-1.41 mSv.

According to the information in Table 2, the total mean dose rate in the closed space of the public schools of districts one and two of Hamadan was 1.2±0.08 mSv as separated by the geographical direction.

Table 1. Mean annual dose in closed space of public schools of districts one and two of Hamadan

Sampling location	Geographical region	Mean of dose rate Sv/h(μ)	SD	Total mean ± SD Sv/h(μ)	Annual dose ± SD (mSv)
District 1	North	0.15	0.01	0.16 ± 0.009	0.08±1.41
	South	0.17	0.01		
	East	0.17	0.009		
	West	0.15	0.006		
	Center	0.17	0.01		
District 2	North	0.11	0.005	0.005 ±0.11	0.044±0.96
	South	0.01	0.006		
	East	0.01	0.005		
	West	0.14	0.005		
	Center	0.11	0.005		

Table 2. Total mean dose rate in closed space of public schools of districts one and two of Hamadan as separated by geographical direction in 2016-2017

Geographical directions	Annual absorbed dose rate ± standard deviation (mSv)
North	1.1±0.06
South	1.21 ±0.15
East	0.96 ±0.04
West	1.41 ±0.08
Center	131 ±0.05
Average	1.2 ±0.08

According to the information in Table 3, the mean range of the annual dose caused by the natural radiation of gamma rays in the closed space of the school buildings of districts one and two in the public schools constructed more and less than 40 years before was 1.2±0.15 and 1.22±0.15 μSv/h, respectively.

According to the findings of the current research, the mean annual equivalent dose caused by gamma ray natural radioactivity in the indoor space of the school buildings constructed less and more than 40 years before was calculated to be 1.22±0.15 and 1.2±0.15 μSv/h, respectively, which were higher compared to the mean global absorbed dose rate based on the population distribution (84 nGy/h; range: 20-200 nGy/h). This could be due to the differences in the concentration of radioactive materials in the soil of these regions.[13]

According to the study by Rostampour *et al*. (Table 4), the total mean annual absorbed dose in the outdoor space of the public schools of districts one and two of Hamadan was 1.11±0.22 mSv, which is significantly higher compared to the annual dose rate in the outdoor space of normal regions (0.57 mSv/y). Notably, a normal region is where the absorbed dose rate is in accordance with the international standards and permissible limits of the absorbed dose.[13] According to the information in Table 4, as well as the studies regarding natural background radiation in closed space and the findings of Rostampour *et al.*, the effective annual dose of the public school students in Hamadan was determined to be 0.83 mSv after the measurements.[13]

In a study conducted in Spain to measure the dose rates of background radiations, the obtained values have been estimated at 230 nGy/h in the school buildings where the outer walls were made of light concrete.[15] In

Pakistan, this value was reported to be approximately 100 nGy/h in the school buildings where the outer walls were made of uraniferous coal clay.[16] The measurements in the granite areas of England have indicated the value of 100 nGy/h for some school buildings that were made of local stones,[17] and the findings are consistent with those regarding the school buildings constructed less than 40 years before. On the other hand, the dose value has been reported to be 200 nGy/h in the school buildings that are made of mud bricks in Jamaica.[18] These findings are consistent with the results of the present study.

Table 3. Annual dosimetry results of public schools based on age of buildings in district one of Hamadan

Schools of district	Geographical region	Building age	Building age	Geographical region	Schools of district
	North	40>	0.12	0.02	0.18±1.08
		40<	0.13	0.02	0.16±1.11
	South	40>	0.15	0.02	0.2±1.31
		40<	0.15	0.02	0.17±1.3
One	East	40>	0.11	0.01	0.11±0.97
		40<	0.13	0.02	0.11±1.17
	West	40>	0.16	0.63	0.22±1.42
		40<	0.16	0.02	0.15±1.44
	Center	40>	0.16	0.02	0.13±1.42
		40<	0.16	0.01	0.11±1.41
	North	40>	0.13	0.02	0.17±1.21
		40<	0.14	0.03	0.11±1.19
	South	40>	0.11	0.02	0.14±0.95
		40<	0.13	0.02	0.11±1.14
Two	East	40>	0.14	0.02	0.1±1.19
		40<	0.14	0.02	0.21±1.2
	West	40>	0.14	0.01	0.26±1.23
		40<	0.16	0.02	0.13±1.16
	Center	40>	0.16	0.02	0.11±1.15

Table 4. Total mean absorbed dose rate and annual effective dose received by public school students in Hamadan based on total open and closed spaces as separated by geographical direction [13]

Geographical directions	Annual absorbed dose rate ± standard deviation (mSv)	Annual effective dose (mSv)
North	0.19 ±1.1	0.89
South	0.25 ±1.12	0.97
West	0.18 ±0.91	0.79
East	0.28 ±1.42	0.68
Center	0.21 ±1.04	0.82
Total mean	0.22 ±1.11	0.83

Since old school buildings are made of materials with low resistance and unfilled pores, it seems that the difference in the dose rate of natural radioactivity could be associated with radon gas leakage from the earth's crust into the buildings of old schools (>40 years). In the upper floors, the amount of the received rays has been measured and reported to be less than the lower floors, which could be due to the distance from the earth's crust, origin of the radiations, and decreased radon gas concentration. These findings are in line with the results of the present study.

Another study in this regard was conducted by Saghatchi *et al*., and the findings demonstrated the mean absorbed dose rate in the closed space of the schools in Zanjan to be 146±25 nSv/h, which is higher than the global mean; this is also in line with the results of the present study.[19]

Lopez *et al.* also investigated the dose caused by natural radiations in students in the granite areas of Spain, and the estimated dose in students was reported to be 0.5-6.05 mSv/y, which was caused by radon gas inside the school buildings. This value is higher than the global mean, and the finding is in congruence with the results of the present study.[15]

Another research in this regard was performed by Rostampour *et al*. to assess the

amount of natural radiation in the outdoor space of the schools in Hamadan, and the value of the natural radiation in the closed space of the schools of Hamadan was also measured. In the mentioned study, the amount of the annual effective dose for the students in Hamadan was determined to be 0.83 mSv as separated by geographical region, and the estimated value is higher than the global mean (0.48 mSv) compared to the UNSCEAR 2000 report.[13] Notably, the amount of the annual effective dose in different countries is within the range of 0.3-0.6 mSv.[20] A similar study was conducted by Gholami *et al*. using a survey meter in Lorestan (Iran) to measure the annual effective dose caused by natural radioactivity in this province, which was estimated at 0.72 mSv; this is consistent with the results of the present study.[20]

In the study by Banzi *et al*. regarding the measurement of the dose rates of background radiation in Tanzania during seven years using the thermoluminescent dosimetry (TLD) method, the mean rate of background radiation in the students of the schools in this city was estimated to be 98 μGy/h, which is consistent with the results of the present study.[21] According to the findings of Shabazi and Danesh in Chaharmahal and Bakhtiari province (Iran), the annual effective dose for the school students was observed to be one of the highest in the area (0.49 mSv), which is consistent with the results of the present study.[22]

The main limitations of the study were the lack of permission to measure radiation in some homes and lack of funds.

Conclusion

The difference between the equivalent doses caused by natural radioactivity in various cities could be due to the varied concentration of the radioactive materials in the soil of these regions. According to the results, the radiation caused by soil in the school students in Hamadan was higher than the global mean (0.5 mSv/y). Therefore, it is suggested that epidemiologic studies be conducted to investigate the possible incidence of chronic diseases considering the incidence of cancer and other disorders associated with radiation and natural radiation among the school students in Hamadan.

Research innovation

Considering that the soil of the surrounding lands of Hamadan Province is used to provide materials for the construction of schools, the natural background radiation received by students and school staff should be reduced in order to diminish the risk of cancer. In addition, the soil concentration of radioactive materials should be accurately determined and analyzed to ensure the health of the individuals who might be exposed to these rays.

Acknowledgements

This study was conducted with the assistance of the HSR Committee of Health Deputy and financially supported by the Research and Technology Department of Hamadan University of Medical Sciences in the form of an HSR project (No. 9407093641). Hereby, we extend our gratitude to honorable deputy and officials, as well as the principals and teachers of the public schools in Hamadan for the cooperation in this research project.

Author contributions

All the authors equally contributed to the preparation of the research.

Conflicts of interest

The authors declare they have no conflicts of interest.

References

1. Zubair M. Natural Radioactivity and Ionizing Radiation Measurements in Environment: Aligarh Muslim University; 2012.
2. Zamanian A, Hardiman C. Electromagnetic radiation and human health: A review of sources and effects. High Freq Electron 2005; 4(3): 16-26.
3. National Research Council. Health risks from exposure to low levels of ionizing radiation. BEIR VII phase 2, National Academies Press; 2006.

4. United Nations. Scientific Committee on the Effects of Atomic R. Sources and effects of ionizing radiation: sources: United Nations Publications; 2000.
5. Taira Y, Hayashida N, Brahmanandhan GM, Nagayama Y, Yamashita S, Takahashi J, *et al*. Current concentration of artificial radionuclides and estimated radiation doses from 137Cs around the Chernobyl Nuclear Power Plant, the Semipalatinsk Nuclear Testing Site, and in Nagasaki. J Radiat Res 2011; 52(1): 88-95.
6. Thomas J, Hulka J, Salava J, Editors. New houses with high radiation exposure levels. High Levels of natural radiation; 1993; Ramsar, Iran.
7. Velayati M. Female rural-urban migration of Azari women in Iran: The case study of Tabriz. Thesis, University of York; 2003.
8. Mjönes L. Gamma radiation in Swedish dwellings. Radiat Prot Dosimetry 1986; 15(2): 131-40.
9. Osmanlioglu AE, Kam E, Bozkurt A. Assessment of background radioactivity level for Gaziantep region of southeastern Turkey. Radiat Prot Dosimetry 2007; 124(4): 407-10.
10. Sohrabi M, Ahmed JU, Durrani SA, Editors. High Levels of Natural Radiation. 3rd International Conference on High Levels of Natural Radiation; 1990 Ramsar-Iran.
11. Radhakrishna A, Somashekarappa H, Narayana Y, Siddappa K. A new natural background radiation area on the southwest coast of India. Health Phys 1993; 65(4): 390-5.
12. Bahreyni Toosi MT, Sadeghzadeh Aghdam A. Assessment of environmental gamma radiation level in Azerbaijan. Iranian J Medical Sci 2000; 3(1): 1-7. [In persian].
13. Rostampour N, Almasi T, Rostampour M, Mohammadi M, Ghazikhanlou Sani K, Khosravi HR, *et al*. An investigation of gamma background radiation in Hamadan province, Iran. Radiat Prot Dosimetry 2012; 152(4): 438-43.
14. Jabarivasal N. Indoor atmospheric radon in Hamadan, Iran. Atmospheric radon indoors and around Hamadan city in Iran: University of Bradford; 2012.
15. Lopez R, Garcia-Talavera M, Pardo R, Deban L, Nalda J. Natural radiation doses to the population in a granitic region in Spain. Radiat Prot Dosimetry 2004; 111(1): 83-8.
16. Butt KA, Ali A, Qureshi AA. Estimation of environmental gamma background radiation levels in Pakistan. Health Phys 1998; 75(1): 63-6.
17. Wrixon AD, Green BMR, Lomas PR, Miles JCH, Cliff KD, Francis EA, *et al*. Natural radiation exposure in UK dwellings. National Radiological Protection Board, Chilton (UK), 1988.
18. Pinnock WR. Measurements of radioactivity in Jamaican building materials and gamma dose equivalents in a prototype red mud house. Health Phys 1991; 61(5): 647-51.
19. Saghatchi F, Salouti M, Eslami A. Assessment of annual effective dose due to natural gamma radiation in Zanjan (Iran). Radiat Prot Dosimetry 2008; 132(3): 346-9.
20. Gholami M, Mirzaei S, Jomehzadeh A. Gamma background radiation measurement in Lorestan province, Iran. Int J Radiat Res 2011; 9(2): 89-93.
21. Banzi F, Msaki P, Makundi I. A survey of background radiation dose rates and radioactivity in Tanzania. Health phys 2002; 82(1): 80-6.
22. Shabazi D, Danesh A. Investigation of cancers incidence relevant to radiation in Chaharmahal and Bakhtiari province during five years (1998-2002). J Shahrekord Univ Med Sci 2004; 6(1): 7-13. [In persian]