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Natural Gamma Radiation in Primary Schools of Zanjan Province

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ABSTRACT

Background: Environmental gamma ray refers to the gamma radiation from terrestrial sources and building materials. In enclosed spaces radiation can become a health hazard leading to potential increase in the rates of lung cancer. The goal of this study is to assess the exposure to natural gamma radiation of children in the schools of Zanjan province.
Method: The natural gamma radiation was assessed in 46 primary schools of Zanjan province. A total number of 75 classrooms were studied. The measurements were performed in classrooms and schoolyards using a Geiger–Muller detector (RDS-110). Alongside radiation measurements, all the data corresponding to the characteristics of each school building were collected.
Results: The results showed that the outdoor dose rate ranged from 82 to 106nSv h^{-1} while gamma dose rate due to inside classrooms ranged from 106 to 137nSvh^{-1}. The findings represented that the highest indoor gamma dose rate belonged to the buildings of more than 30 years and metal frame and brick ($P<0.05$).
Conclusion: We concluded that the effective dose due to gamma radiation from terrestrial sources and building materials for students of primary schools in Zanjan province (0.83 mSv) was higher than worldwide average of the annual effective dose (0.48 mSv).

1. Introduction

The measurement of natural gamma radiation is one of the most important subjects in health physics [1]. Environmental gamma ray generally refers to the gamma radiation from terrestrial sources and building materials. There are two main contributors to natural radiation exposures: High-energy cosmic ray particles occurring on the earth's atmosphere and radioactive nuclides that are originated in the earth's crust [2]. Building materials are the main source of indoor gamma radiation, besides terrestrial and cosmic radiation.

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All stone-based building materials contain radioactive nuclides [3, 4]. The knowledge of radioactivity levels of materials used in the Buildings and in ceramic industries is therefore important in the assessment of possible radiological hazards to human health [5-7]. This knowledge is essential for the development of standards and guidelines for the use and management of these materials [8, 9]. There is abundant evidence that exposure to ionizing radiation can cause cancer [10-12]. In enclosed spaces such as classrooms, radiation can accumulate and become a health hazard leading to potential increase in the rates of lung cancer [13-15]. Ionizing radiation is one of the few established exogenous risk factors for childhood leukemia [16, 17]. Some findings show a statistically significant positive trend in the risk of childhood leukemia with an increase of dose due to naturally occurring gamma radiation [18-21].

The measurement of gamma dose rate is one of the scientific subjects that attracts most attention. Gamma dose rate measurements were performed in 512 schools of Greece and no correlation was found between indoor gamma dose rate and indoor radon [22]. The same study was performed in Tamilnadu, India. They concluded that the average absorbed dose rate in that area was slightly greater than the world average value [23]. An Egyptian study found that the population-weighted annual effective dose due to terrestrial gamma radiation indoors was in the range 0.025-0.345mSv [6].

Many studies have been performed to show correlation between natural radioactivity and building materials [7, 24, 25]. Peter de Jong and Willem van Dijk have reported that the chemical composition of the building material has no significant rate [24]. While Chowdhury, Alam and Ahmed found that the concentrations of 226Ra radionuclide were approximately equal in brick, gravel, mortar and soil. Concrete and cement were slightly higher than brick and others, but in phosphogypsum 226Ra is very high relative to others. The 232Th activity in brick, gravel, cement, concrete and soil are approximately equal to that of mortar and soil [25]. The activity concentration of 226Ra, 232Th and 40K in samples of some Jordanian building materials were determined. Their result showed that the concentration of natural radionuclides was found to be within the average worldwide ranges. The granite samples represented an exceptional case in which 232Th activity concentration exceeded the worldwide average activity concentration [26]. Nuccetelli. C et al., tried to develop a procedure to account for average concrete values of thickness and density. Their procedure was unfit in case of significantly different density and/or thicknesses of the building materials under examination [27].

The effect of age and building material on the radon concentration was studied in Nigeria as well. They have found that radon concentration schools of over 10 years old was lower than in schools under 10 years old. The average radon concentration measured for the buildings constructed of concrete was lower than buildings constructed of mud brick [28].

Authors determined the natural gamma radiation in homes of Zanjan city by Rados survey meter in 2008. The results showed that the lowest and highest average doses indoors were (129± 24) nGy/hand (164 ±23) nGy/h, respectively with an average of (146 ±25) nGy/h [29].The same study was done in schoolyards of cities of Hamedan province (southern neighbor of Zanjan). The study showed that the annual effective dose of students was 0.83 mSv [30].The study on concentrations of indoor radon in central Iran indicates that despite few extraordinary high concentrations, average annual concentrations of indoor radon are within ICRP guidelines. The authors have used passive diffusive samplers with LATEX polycarbonate films as Solid State Nuclear Track Detector (SSNTD) [31].

The goal of the present work is to increase the number of gamma radiation measurement locations in the province of Zanjan. The new data will allow us to evaluate the effective gamma dose rate both indoors and outdoors in more cities of Zanjan. We will focus the attention on the study of gamma radiation in school buildings. Therefore, we will assess the exposure to radiation of children and workers in the classrooms.

2. Materials and Methods

Measurements were carried out in 46 schools in 7 cities of Zanjan province. Zanjan province is located in the north-west of Iran (36.67518 N;

48.48458 E). Its average height is about 1600 m and the total area of 22150 km2 (Fig. 1). One of the prominent features of magmatic highlands in the north of the Zanjan province is the existence of large granitic and granodioritic bodies in the Tarom mountain ranges. Mineralization of gold, copper, lead–zinc and Tarom mountain ranges. Mineralization of gold, copper, lead–zinc and kaolin are associated with these hydrothermal alteration halos.

A total number of 75 classrooms were studied in Zanjan (The capital city), Abhar, Khoramdarre, Khodabande, Mahneshan, Ijrood and Tarom [39, 10, 8, 8, 4, 2 and 4, respectively]. All schools were state schools and non-coeducational with 41 classrooms only-girl type and 34 only-boy type. General specifications of elementary schools are shown in Table 1.

Due to the possibility of multi-floor schools in some cities, a class was chosen from each floor. Due to the limited number of primary schools in Mahneshan, Ijrood and Tarom, the measurements were carried out in all schools. However, in Zanjan (zones 1 and 2), Abhar, Khodabande, Khoramdeh, we performed cluster sampling because of the large number of schools in these cities.

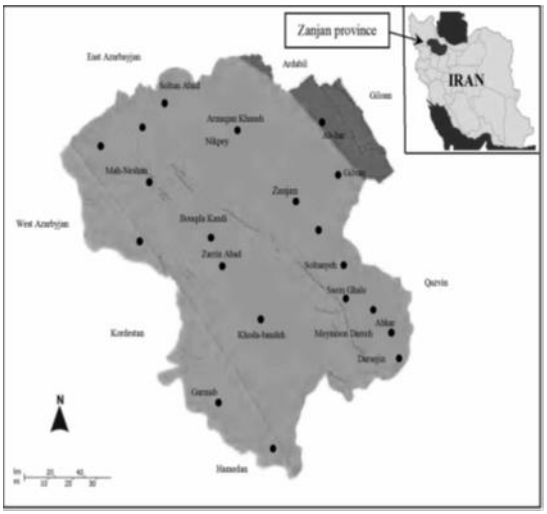

Fig. 1: Map of Iran representing the study areas in this paper.

In these cases, the areas North, South, East, West and center of each of the mentioned cities were intended as a cluster. To determine the background radiation, in the first step the dose rate from natural background gamma radiation indoors (classrooms) was determined, then the measurements were repeated for outdoors (schoolyards) in the 2nd step. The dose rate from background gamma radiation in each city was accomplished using a Geiger–Muller detector (RDS-110) calibrated by 137Cs in Rados Company in Finland (Radiation source: 137Cs, 662 keV, dose rate 300 mSv/ h). A GPS system was used to obtain information about the geographical position that allows easy reference to each selected point for other research. Alongside radiation measurements, we also collected data corresponding to the characteristics of each school building such as year of construction, building materials, type of ventilation, heating system and number of windows. The statistical analysis was performed by using SPSS 10 and R (R Core Team (2015).

3. Results

This study was performed in the educational buildings of Zanjan province. We studied a total number of 2060 students in 46 schools and 75 classrooms of 46471m2 infrastructures. The average life of school building was 15 years with a minimum and maximum of 5 and 23 years respectively. The type of building materials used was 52% brick, 42.7% Concrete and 5.3% adobe. The wall covering materials of classrooms were 85.3% stone and 14.7% non-stone and the wall covering above 120cm was 82.7% oil and plastic color, 4% wallpaper and 13.3% other materials. Our results showed that 64% of the classrooms were on the ground floor, 29.3% on the first floor and5.3% in basements and 1.4% on the second floor. According to our data, 72% of the classrooms had a size bigger than 30m2 and 1.3% less than 12m^2.

The ratio between window dimension and classroom area in 64% of the classrooms was (15 - 25) % and in13.3% over 25%. Ventilation systems were mechanical in 1.3% of the classrooms and the rest of schools had natural ventilation. 82.7% of the classrooms had a central heating system, while 1.3% owned oil heaters and the rest gas heaters.

Table1: General specifications of elementary schools studied. The number of classrooms is added since it is very common for the same school building to have different classrooms.

city	Number of primary schools	Total number of classrooms	Number of school building	Number of classrooms	Number of students
Zanjan	104	577	20	39	1156
Abhar	41	108	7	10	281
Khoramdare	20	85	5	8	198
Khodabande	23	74	5	8	205
Mahneshan	3	36	3	4	84
Tarom	7	25	4	4	88
Ijrood	3	14	2	2	48
Total	201	919	46	75	2060

The measurements of background gamma radiation in outdoor and indoor of primary schools in Zanjan province are 0.84mSv. Fig. 2 shows the results obtained in terms of bar plot using the mean values found for each city. The results showed that the maximum and minimum dose rates due to outdoor gamma radiations are (104 nSv h^{-1}) and (82 nSv h^{-1}), respectively in schools of khoramdare and Taroom. It can be observed that indoor radiation dose rate ranged from (110 nSvh $^{-1}$) to (128 nSv h^{-1}) while the mean is (115 nSv h-1). The maximum and minimum values belonged to Abhar and Khoramdare and both Mahneshan and Khodabande, respectively for effective gamma dose rate indoors. The results show a more homogeneous picture for the same parameter measured outdoors.

To evaluate the annual effective dose (E) expressed in µSv per year due to natural gamma radiation we used equation (1),

E = T×A (0 .2 Dout + 0.8 Din),

Where T is the number of hours in a year (8760 h), A is the conversion coefficient which is 0.85 for children with the age of 7-12 years and 0.2 and 0.8 are occupancy factors for indoor and outdoor respectively. D is the gamma dose rate outdoors and indoors respectively.

This study has provided information on the average indoor and outdoor gamma dose rate. The mean indoor gamma dose rate worldwide is equal to 120 nSv h^{-1} according to UNSCEAR 2000 Annex B, and the highest values (95-115 nGy/h) are found in Hungary, Malaysia, China, Albania, Portugal, Australia, Italy, Spain, Sweden, and Iran, which reflects the wide use of stone or masonry materials in buildings. As is shown in results in Table 2, indoor gamma dose rate ranged from (106 nSv h^{-1}) to (137 nSv h^{-1}) while the mean is (120 nSv h-1). The mean height of Abhar is 1575 m and a granite quarry and copper and silica mines are active in this area. Tarom is placed in Tarom valley whose maximum height is 750 m. The outdoor gamma dose rate as shown in Table 2 ranges from (106 nSv h^{-1}) to (82 nSv h^{-1}) related to schools of Abhar and Tarom respectively.

Fig. 3. Shows the frequency distribution of our data corresponding to the two types of gamma radiation measurements performed. We can observe in this Figure that all measured data indoors correspond to a probability distribution that is normal type according to the Shapiro test (p-value = 0.116329).

However, if we perform the same Type of analysis with data from outdoor measurements, we do not find normal distribution. To look into our results, we have represented the range of data obtained for each city using the box plot graphs. This graph can be seen in Fig. 4.

The representation using this type of graph reveals that the data distribution is quite homogeneous in all cities. However, we can see some outliers in Abhar and Khodabande for the outdoor gamma dose rate.

Table2: Summary of the annual effective dose from natural gamma radiation in elementary schools of Zanjan province. Values of gamma dose rate are given in nSv per hour and the annual effective dose is expressed in mSv.

city	Effective dose	Mean outdoor gamma dose rate	Mean indoor gamma dose rate
Zanjan	0.82	100	113
Abhar	0.97	106	137
Khoramdare	0.87	99	121
Khodabande	0.76	86	106
Mahneshan	0.77	84	109
Tarom	0.81	82	137
Ijrood	0.86	102	119
Mean	0.83	94	120
Worldwide mean	0.48		84

The city of Khodabande also shows an outlying value if we summarize the data of indoor gamma dose rate. Mahneshan and Taroom also have outliers for the same type of measurements.

We have tried to determine if values of indoor and outdoor gamma dose rates are statistically different by carrying out hypothesis testing. In three of the cities there was no evidence to decide whether those values were different (Mahnesan, Khodabande and Ijrood). However, the case of Ijrood is rather particular because we had only two school buildings measured. The rest of the cities in our study showed evidence of difference between values of indoor and outdoor gamma dose rate.

We have also studied the linear relationship between both variables and we found no evidence of such a relationship. In this study we checked the relation between different factors with the value of gamma radiation calculated in the schools. The findings of post-hoc test represent that there is a significant difference between schools built under 5 years ago and those with an age older than 30 years ($p < 0.05$). The highest indoor gamma rate was found in those buildings older than 30 years. The same result was found in a study of indoor radon in Italy. They showed that evidence of higher radon levels was found in the oldest buildings (32). The findings also represented that metal frame and brick in comparison with reinforced concrete was associated with higher gamma dose rate but the other masonry did not show significant differences ($p < 0.05$).

We conclude that buildings aged over 30 years and brick and adobe buildings have significant differences in effective dose compared with other schools ($p < 0.05$).

Regarding the relationship between class size and the amount of gamma dose rate in terms of statistical significance, the most discrepancy was related to the class size of 12-20 m2 and over 30 m2. The lowest value of gamma radiation was obtained in the smallest size classrooms ($p < 0.05$).

The ANOVA test showed that there are no significant differences between indoor gamma radiation and the wall covering materials ($p > 0.05$). Unexpectedly, there is no significant relationship between gamma radiation and the number of class floors ($p > 0.05$).

This result also applies for the window dimension/class area. We found that window dimension has no significant effect on value of indoor gamma dose rate ($p > 0.05$).

The result of Kruskal- Wallis test showed that there were no significant differences between the mean gamma radiations in different cities of province ($p > 0.05$).

4. Discussion and Conclusions

We conclude that the effective dose for students of primary schools of Zanjan province (0.83 mSv) was higher than worldwide average of the annual effective dose (0.48 mSv).

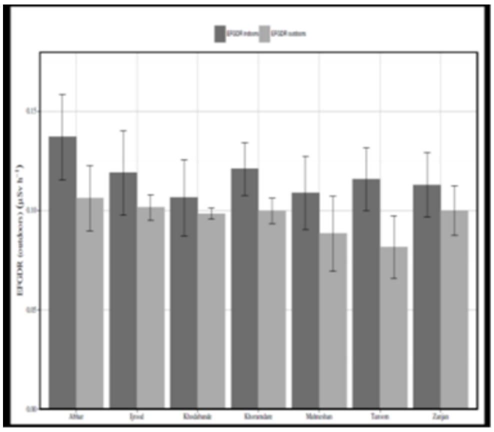

Fig. 2: Bar plot with the average values obtained in this study corresponding to outdoor and indoor effective gamma dose rates. The error bars represent one standard deviation from the mean value.

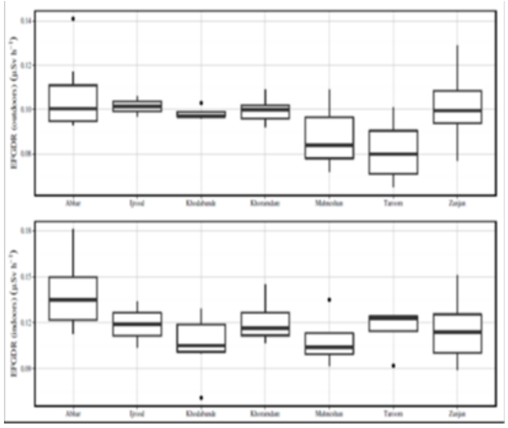

Fig. 4: Box plots of our results in each of the measured cities both outdoors and indoors.

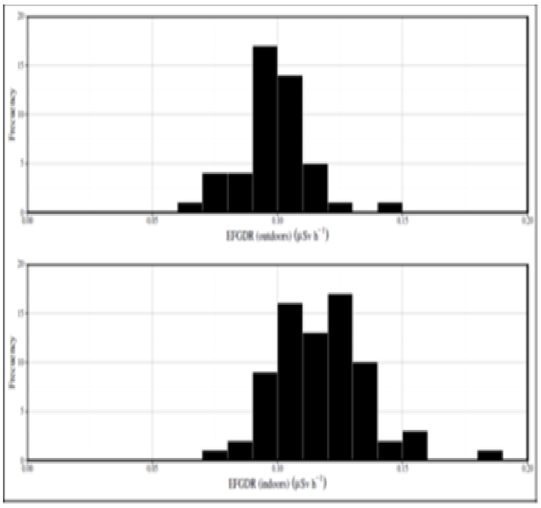

Fig. 3: The frequency distribution of our data corresponding to the two types of gamma radiation measurements performed.

It seems some complementary studies are necessary to gain complete information in schools of Zanjan province such as measurement of radon concentration in indoor areas, and epidemiological studies on cancer and the risk assessment of different building materials could be very helpful.

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