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Evaluation of the Effect of Color on the Natural Radioactivity of Marble Collected from Zahedan and Zabol Cities

Fatemeh Zakieh Tohid 1, Hadi Nakhzari Moghadam 1*, Masoume Farsizaban 1, Zeinab Yazdi Sotoodeh 2, Vida Sargazi 2

1. Department of Medical Physics, Faculty of Medicine, Zahedan University of Medical Sciences, Zahedan, Iran
2. Department of Radiology, Faculty of Paramedicine, Zahedan University of Medical Sciences, Zahedan, Iran

***Corresponding Author:** Nakhzari Moghadam Hadi, Medical Physics Department, Faculty of Medicine, Zahedan University of Medical Sciences, Zahedan, Iran

Email: h_nakhzari@yahoo.com

ABSTRACT

Background: Humans in their environment are always exposed to radiation from various sources, including that of building materials. Since they spend about 80% of their time in enclosed environments, the probability of radiation is high.

Objectives: This dosimetric study was carried on marble stones used in buildings of Zahedan and Zabol cities in 2020. The purpose was to determine the relationship between stone color and its radioactivity.

Methods: For the purpose of the study, the researchers identified and prepared a list of supplied building stones in stone shops of Zahedan and Zabol cities during December 2020 to December 2021. A total including 75 marble samples, were collected by an MKS pen dosimeter in three operating modes: gamma equivalent dose rate (EDR) measured in microsievert per hour, equivalent gamma dose (ED) calculated in milliseconds, and beta flux density, measured in parts per square centimeter per minute (part/cm^2.min).

Results: The highest EDR mean in marble stones belonged to white marble (0.13 μSv/h), while the lowest was found in cream-colored marbles (0.06 μSv/h). White samples had the highest mean of beta flux density in marble stones, 0.0026 part/cm^2.min. The beta flux density equaled zero in five samples of marble. The ED value for all samples was set to zero.

Conclusion: The maximum amount of EDR and beta flux for marble stones concerned white color, which was slightly higher than the global average. The average EDR for travertine was slightly more than that of marble and the permissible limit. Also, the beta flux in marble stones, between 0.0016 and 0.0026, was higher than travertine stones, which is less than the allowable limit. The mean value of beta beam flux density in the open air was zero. In all samples, the amount of ED was zero. The amount of background radiation in the open air of Zahedan and Zabol cities corresponds to its average value in the world.

Keywords: Dosimetry, Marble , Zahedan, Zabol.

Background

Humans are always exposed to various environmental threats, such as electromagnetic waves, radioactive radiation of building materials, and background radiation(1). The largest share of radiation during the human lifetime, which comprises about 90% of radiation to which human is exposed, is that of natural sources and cosmic rays. Internal and external exposure of humans to radiation due to natural resources is not inevitable(2). According to UNSCEAR and IAEA reports, the average background radiation dose is estimated as 2.4 millisieverts per year. Out of this value, the share of external radiation from natural resources is on average 0.48 millisieverts per year(3, 4).

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In the meantime, indoor radiation is mainly caused by two factors: cosmic rays and emitted rays from radionuclides that are present in building materials such as rock and soil(5). According to studies on building materials, including building stones, small quantities of radioactive elements such as uranium and thorium are present in such materials(6, 7). Granite rocks, for example, contain an average of 4.7 ppm uranium(8). In sedimentary rocks, the concentration of uranium is reported to be about 2 ppm (9). However, in addition to their type, radioactivity of these rocks also depends on how and where the composition of molten rocks is formed (10). These stones have different colors that are related to the type of elements that make them up.
Mineralogically, building stones such as granite are composed of coarse quartz minerals, potassium feldspar, and sodium plagioclase (11). This stone has been widely used in buildings due to its strength and decorative appearance (12). In terms of application, building stones are categorized based on where they are used in the building. For example, marble and granite are used in the facade of the building (13). Meanwhile, radon gas emitted from these sources is an influential factor in the dose received by the general public (14, 15). The International Commission on Radiological Protection (ICRP) has recommended a reference level of 300 $Bq.m^{-3}$ for residential buildings (16, 17). Because humans spend about 80% of their time in indoor environments and are in close contact with these materials, the probability of radiation is high (18). Although the dose received is low, there is a possibility of ionizing radiation such as cancer (19).

Several studies have been conducted to evaluate the amount of natural background radiation in Iran and other countries in recent years. Studies on the absorption dose of people inside buildings are less than those on outdoor spaces (5). The amount of natural background radiation in the open-air caused by cosmic gamma rays was examined in a study in Hamadan province (20). According to this research, the effective annual dose received by Hamedan residents and related cities was determined to be 0.83 mSv, which is higher than the global average of 0.48 mSv compared to the 2000 UNSCEAR report (21). Studies conducted in previous years in areas with high natural radioactivity in the city of Ramsar have also reported the concentration of radon gas in the region up to 31000 $Bq.m^{-3}$ and a resulting annual dose between 2.4 and o 71.74 (22 & 23).
In 2001, the annual dose of environmental gamma radiation in Khorasan province was estimated by Bahreini Tusi and Abdolrahimi. Based on their measurements, in the closed spaces, the highest dose rate of 157.4 nSv/h was related to Gonabad city. Gholami et al. (2011) conducted a study in Lorestan province using servimeter and measured the effective annual dose by natural radiation in this province as 0.72 mSv (25). Based on another study conducted in Zanjan in 2009, the effective annual dose of Zanjan residents was 0.87 mSv (26). In 1999, a study was conducted to measure the dose rate of internal gamma ray using thermoluminescence dosimetry, which reported the absorption dose rate in closed space between 0.01 to 0.037 Gy/h per hour (27).
In dosimetry of marble stones by Dianti Tilki et al. (2008) in Sari, the average gamma dose rate obtained was 0.07 microsieverts per hour (7). Al-Saleh (2007) in Riyadh, Saudi Arabia, in his study, attempted to measure the amount of radioisotopes of marble, which indicated the following values: ^{238}U (0.71-44.1Bq/kg), ^{226}Ra (0.36-32.4 Bq/kg), and ^{40}k (0.68-897.1 Bq/kg) (28). An independent study was conducted on marble stones by Malakoutian et al. (2013) in Kerman (29). A study was conducted in 2009 by Taghi Bahreini Tusi et al. (2009) in Kurdistan province. According to this study's results, the highest indoor dose rate was h/nSv 25±166, as indicated for Baneh city, which was significantly higher than the global average (30). Tavakoli et al. (2013) evaluated the effect of granite rocks' color on their natural radioactivity (31).

Objectives

The purpose of the present study was to measure the dosimetry of marble stones used in buildings of two northern cities of Zahedan and Zabol provinces within December 2020 to December 2021 as an attempt to shed light on the relationship between stone color and radioactivity.

Method

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This study was conducted using the survey method on all types of stones offered in stone shops of Zabol and Zahedan city in 2020. First, we referred to the stone shops of each of these cities and made sure that the owner has enough information about the stones. In doing this, information about available types of building stones used in the city was collected such that all items of stones in terms of type and location were listed. In the relevant list, the type of stone, its location, and color were specified. Five pieces with 40 X 40 cm dimensions were collected from each stone as a sample (29).

The dose in each sample was measured by separating the sample from the rest of the samples at a great distance from the others by placing the dosimeter less than 10 cm from the target stone. A calibrated MKS-05 dosimeter device was used for this purpose.

The sensitivity of the device ranged from 0.01 to 10 microsieverts per hour. When the dose of each stone was fixed on the device, the revealed value was read. The reading was carried out three times for each sample to ensure the accuracy of the procedure, and the average was used. Measurements in each sample were performed in three steps.

1. First stage: Gamma dose rate EDR (Equivalent dose rate), measured in microsievert per hour.
2. Second stage: The equivalent dose, measured in millisieverts.
3. Third level: Determination of surface beta particle flux density, performed in terms of part/cm2.min.

To calculate each sample's gamma dose rate, we placed five pieces of stone from each sample next to each other and placed the dosimeter at a distance of less than ten centimeters. Then, the dose rate was measured and recorded for one hour. The measurements of beta dose and flux were performed in the same way. Regarding the arrangement of the stones, there was a suitable distance between different types of stones.

To ensure the accuracy of the process, the reading was repeated three times for each sample, and the average of the numbers was used. In this study, the background dose was measured. A total including 75, were obtained from stone shops for dosimetry. The data were analyzed using SPSS software.

Results

Table 1 presents the types of stones used in the Zahedan and Zabul provinces according to their color.

Table 1: Typology of stones used in Zahedan and Zabul

Marble	Color
Shahreza	White
Kerman Type 1	White
Kerman Type 2	Red
Kerman Type 3	Dark green
Tabriz	White
Semirom	White
Shiraz	White
Mashhad type 1	Red
Mashhad type 2	pink
Isfahan Type 1	Red

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Isfahan Type 2	White
Isfahan Type 3	Cream
Khorramabad	White
Diplomat	White
Borujerd	Cream

Table 2: EDR and flux density of beta particles of stones used in Zahedan and Zabol

The color of the stone marbles	Average EDR	Standard deviation EDR	Average flux density of beta particles	Standard flux deviation density of beta particles
1	0.1	0.02	0.002	0.001
2	0.08	0.06	0	0
3	0.08	0.03	0.000667	0.00057735
4	0.1	0.03	0.001	0.001
5	0.11	0.03	0.000333	0.00057735
6	0.07	0.01	0.002333	0.001527525
7	0.07	0.02	0.001667	0.00057735
8	0.09	0.04	0.002667	0.001527525
9	0.13	0.01	0	0
10	0.09	0.04	0	0
11	0.13	0.03	0	0
12	0.12	0.07	0.001667	0.001527525
13	0.06	0.02	0.000667	0.00057735
14	0.09	0.01	0.001	0
15	0.13	0.06	0.001667	0.00057735

Figure 1 and Table 2 show the EDR level in marbles. As can be seen, the highest mean EDR in marbles was seen in white stones (0.13 μSv/h), while the lowest EDR belonged to cream-colored stones (0.06 μSv/h). None of the marble samples had an EDR above 0.2 μSv/h. The range of EDR changes in marble was between 0.06 to 0.13 Sv/h.

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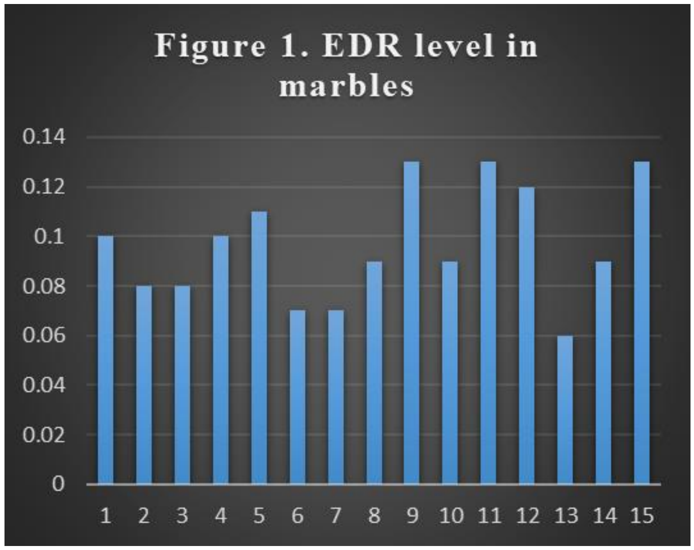
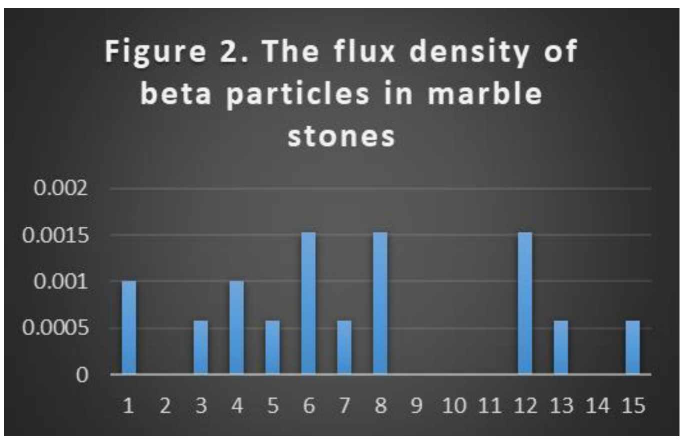


Figure 2 and Table 2 give information about the flux density of beta particles in marble rocks. The highest average for beta radiation flux density in marbles was observed in white stone samples (0.0026 part/cm^2 .min). However, five samples of marble stones had a beta beam flux density equal to zero. The range of flux density changes of beta particles in marble was between zero and 0.0015 part/cm^2 .min.



Changes in EDR level and Changes in the flux of rock types tested in the rock types examined are presented in Table 3.

Table 3: Amount of EDR changes in the rocks

Type of stone	Standard deviation	Average	At least	Maximum
Marble	0.023	0.096	0.06	0.13
	0.0009	0.001	0	0.0026

Discussion

The annual external gamma dose emitted by building materials, depending on the part of the building they are used, is given in EC (1999). Therefore, the amount of virtual radiation that stones can emit depends on their location in the building (11). The gamma activity concentration emitted from the surfaces is specified by the European Commission which clarifies the annual dose of the external gamma radiation emitted by the surfaces (32, 33).

According to the permissible values mentioned and the findings of this study, it can be concluded that the EDR level for white marble was slightly higher than the global average. The marble rocks results showed that the range of average EDR changes was less than the allowable limit. The findings of direct measurements in travertine rock samples revealed that the range of EDR changes was slightly more than the allowable limit as well. The highest beta beam flux density observed in marble stones was between 0.0016 and 0.0026, which is less than the permitted range.
The highest amount of EDR has been previously observed in the sample of Isfahan crystalline marble and Diplomat and Mahkam-e-Kerman marbles (approximately 0.13). Therefore, because of the highest EDR level identified in the travertine samples of Isfahan and Abbasabad (approximately 0.13 to 0.14), it is necessary to make more accurate measurements on these stones. The amount of background radiation in the open air of Zahedan and Zabol cities equals its average in the world.

The average value of EDR in marbles was equal to 0.096 vSv/h. Also, its value for travertine was 0.103 vSv/h, almost close to each other but slightly higher for travertine than marble. In a study conducted by Dianati Tilki and Yazdanifar in Sari (2008), the average EDR in marble was measured as 0.07 microsievert per hour. The average value of beta beam flux density in marble stones was 0.001 part/cm^2. min,. This indicates a higher beta beam flux in marble than in travertine stones. The mean value of beta beam flux density in the open air and the amount of ED in all samples was zero.

White stones had the maximum amount of EDR and beta flux in marble stones, while the maximum amount of EDR and beta flux for travertine was seen in cream-colored stones.

Conclusions

Since the amount of alpha and other ionizing radiations were not determined in this study, there is a possibility of radiation in some rocks that may harm people's health when used in facades and interior decoration.

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Footnotes

Authors' Contribution: Study concept and design, Acquisition of data, Analysis and interpretation of data and Drafting of the manuscript, Hadi Nakhzari Moghadam, critical revision of the manuscript for important intellectual content, Farsizaban Masoume

Conflict of Interests: The authors declare no conflict of interest.

Ethical Approval: This study is approved by the ethics committee of the ZUMS (code: IR.ZAUMS.REC.1398.028).

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