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Investigation of the influence of buildings on the total gamma background radiation

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The influence of buildings on the total gamma background radiation was investigated. The total gamma radiation between a building made from bricks and a field, which are 100 m apart (away from the influence of other buildings), was measured using a scintillation detector. Measurements of ambient equivalent dose rate at different heights above the soil and a horizontal distance from 0.1 m – 100 m in variable steps were taken. A new approach was developed to assess the contribution of gamma background radiation from the soil and the building to the total gamma background radiation. It was obtained that the gamma background radiation contributed by buildings, greatly affects the total gamma background radiation up to a distance of 2 m, at which there was a significant decrease in the total gamma background radiation. The percentage of the building that contributes to the total gamma background radiation is noted to be between 4 – 29% of the total gamma background. This shows that most of the background radiation in the environment is contributed by the gamma background radiation in the soil. Also, the annual equivalent dose received by a person who sits near the building was 0.09 mSv, which was higher than an adult who works far away from the building (0.08 mSv). Both were however less than the global level. It also was found that the best place to install a detector for measuring gamma radiation was found to be a distance of 1.5 m away from the building.

Keywords: buildings, gamma background radiation, ambient equivalent dose rate, soil, annual equivalent dose.

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INTRODUCTION

There are two main sources of ionizing radiation; these are man-made and natural radiation. Natural radiation can be found everywhere and can be classified into four sources; cosmic radiation, terrestrial radiation, inhalation, and ingestion. Cosmic radiation is made up of particles that move very fast which includes proton molecules that when emitted enters the earth's crust and are absorbed by humans [1]. This radiation mostly comes from the sun and other celestial bodies such as the stars. Radionuclides that mainly contribute to natural radiation include uranium, potassium, and thorium [2]. Some places where natural radiation can be found include the materials used for building. The easiest way by which humans are exposed to radiation is by inhalation of radioactive gases, which emanate from the soil. Some of these radioactive gases include radon, which is a daughter decay products of uranium. Radon mostly increases the gamma background radiation in the soil and when inhaled in large quantities, affects human health [3]. The amount of radon in the soil is increased due to weather conditions and factors such as the amount of precipitation, depth of snowfall, temperature, and so on [4,5]. The amount of gamma radiation at a particular place also depends on the geological and geographical structure of the place [6]. Several works have been done on the gamma background radiation of buildings and soil. This is done by measuring the gamma dose rate of both building and soil. According to Medeiros et. al., [7] on how soil and buildings influence outdoor gamma dose rate in Sao Paulo, Brazil. The average gamma dose rate that was contributed by soil was found to be 80.9 ± 0.642 nSv/h and also it was found that the percentage contributed by building to the outdoor ambient gamma dose rate was about 35% with about 65% being contributed by soil for the measurement taken at 1 m height above the soil. Buildings are a source of background radiation because the materials such as cement, sand concrete and so on used in their construction contain background radiation. Hence assessing the contribution of total gamma background radiation of building and soil as a percentage is very important since most humans live in buildings that are made of cement, gravel, and sand which contain gamma background radiation sources [8]. This goal was actualized by measuring the gamma background radiation (dose rate) between a building made from bricks and a field, which were 100 m apart, and hence finding the percentage the building contributed to the total gamma background radiation.

In this work, a method for assessing the contribution of total gamma background radiation of building and soil as a percentage was developed.

MATERIALS AND METHODS

In this study, a scintillation detector (BDKG-03) was used. The BDKG-03 is a highly sensitive scintillation counter with a sensitivity of 350 (imp/s)/(μSv) for ^{137}Cs which is used to measure gamma dose radiation. It measures gamma background radiation within the energy range of 50 keV – 3 MeV. It also measures the ambient equivalent dose of gamma radiation within the range of 0.03 μSv – 10 mSv and that of power ambient equivalent gamma radiation dose in a range of 0.03 – 300 μSv/h.

Tomsk is a city in Siberia, Russia. It lies in the south-eastern west Siberian Plains in the southwest of the Siberian Federal District. The area chosen for this study was between a building and a field, which are 100 m apart. The building is located at a longitude of 56.4681594 and a latitude of 84.9352326 close to a forest with no building more than 100 m away (Figure 1).

Fig. 1. A map of the study area

To measure the total gamma background radiation, the ambient equivalent dose was first taken in steps of 50 cm from 10 cm to 2 m away from the building at height in steps of 50 cm from 10 cm to 1 m above the ground.

After 2 m, measurements were taken in steps of 1 m from 3m to 10 m and in steps of 10 m from 20 m to 100 m away from the building with height in steps of 50 cm from 10 cm to 1 m above the soil as indicated in Figure 2.

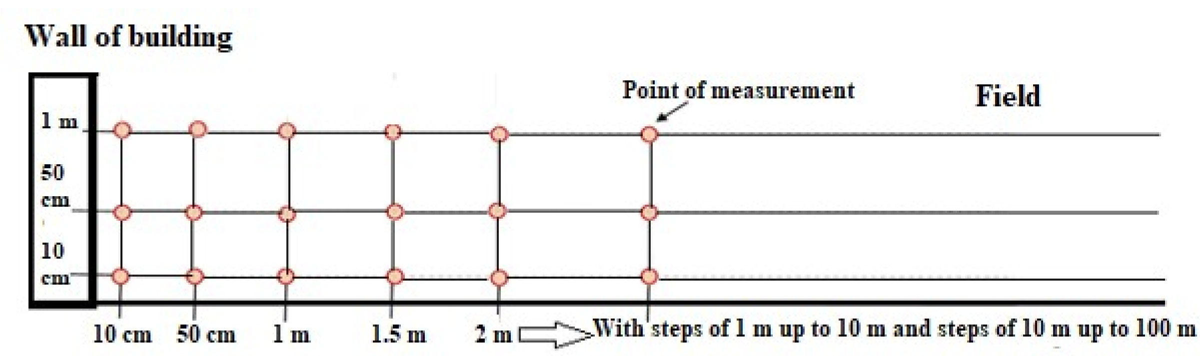

Fig. 2. Scheme of measurement

All measurements were taken at a time interval of 5 minutes. A graph of dose rate against distance was plotted to find the coefficient of absorption in the air as in formula: $\exp(-\mu x)$ Where μ is the coefficient of absorption in air, x is the distance.

The contribution of gamma radiation from building and its percentage to the total gamma background radiation was calculated using equation (1) and (2) respectively;

$$H_b(x) = H(x) - H(20), \quad (1)$$

$$P = \frac{H_b(x)}{H(x)} \times 100\%. \quad (2)$$

Where $H_b(x)$ – dose rate influenced by only building, $H(x)$ – dose rate at x m, x – distance, m; 20 m was chosen as base background value because there was a significant decrease in dose rate away from building far that 20 m.

The annual equivalent dose was then calculated using the ambient dose rate measured.

$$E = H \times OF \times T \times CF \quad (3)$$

Where E - the annual effective dose, H – dose rate, OF – outdoor occupancy factor = 20%, T – time converted from year to hours = 1 year = 8760 hr, CC – conversion coefficient for an adult = 0.7 for converting absorbed dose in the air to effective dose in humans [9].

RESULTS AND DISCUSSION

This section presents and discusses the measurement results of this study. Figure 3 shows the dose rate and distance for different measurements of height above the soil surface.

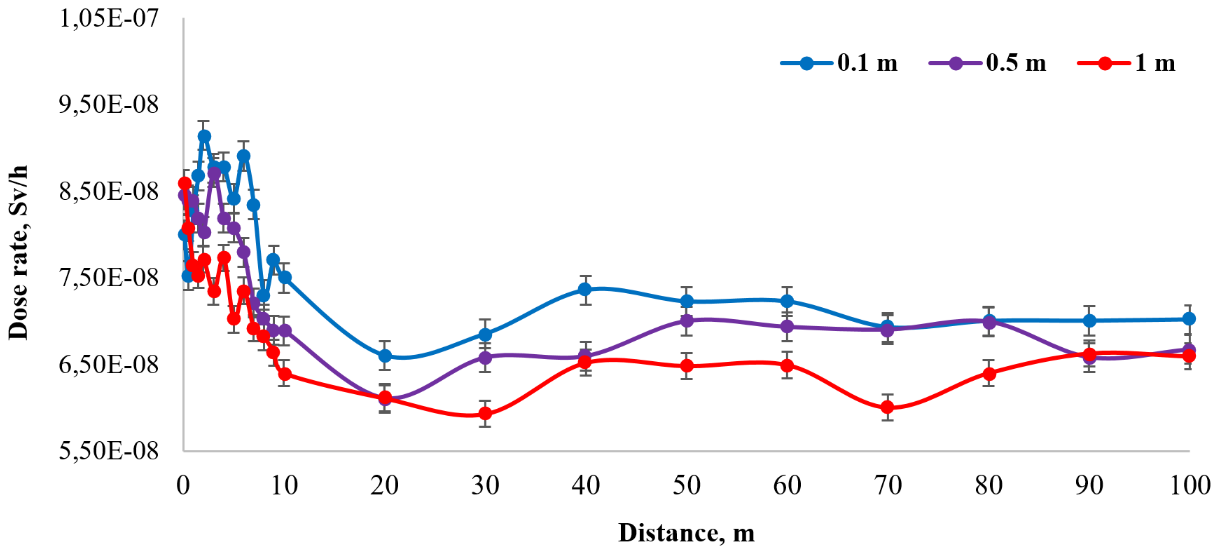

Fig. 3. Dependence of dose rate and distance for the different heights

From the graph, it can be seen that generally, the dose rate decreases as we move further away from the building and as we measure above the soil surface. Also, the dose rate from 20 – 100 m decreases significantly because the gamma background radiation was influenced by only soil since the building was further away. Furthermore, the dose rate decreases proportionally with distance squared. The dose rate from a distance of 0 - 10 m was higher because the gamma background radiation from both building and soil contributed to the total gamma background radiation. Besides, for measurement of dose rate above soil surface at a height of 0.1 m and 0.5 m, the results obtained were distorted and hence they were not decreasing close to exponential. This might have been due to the amount of radon concentration present in both air and soil. It might also have been due to changes in the weather condition and the presence of thoron in the environment. Also for all cases, there is a decrease in dose rate at a distance from 0 cm - 10 cm. This is mainly because of the presence of concrete laid around the building. The ambient dose rate of each measurement taken for 5 minutes ranges from 65.9 nSv/h to 85.92 nSv/h. The error for a single measurement ranges from ± (0.03 – 0.04) nSv/h. The distance 0 cm corresponds to the wall of the building made from bricks. For this work, due to the reasons stated earlier, measurement taken at 1 m height is mostly considered.

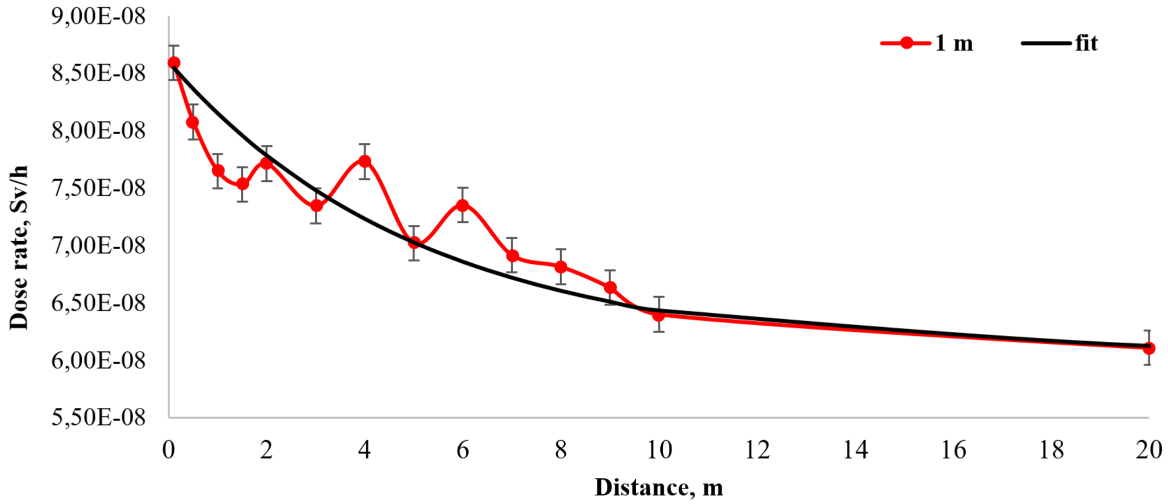

Fig. 4. Dependence of ambient dose rate against distance from 10 cm – 20 m and single exponential fit curve

Figure 4, shows that there was a decrease in gamma dose rate at a distance from 0 cm – 10 cm. This is due to the presence of concrete that is laid around the building. Concrete contains a smaller amount of radionuclides, which contributes to the gamma background radiation such as radon, hence the notable decrease in dose rate from 0 cm – 10 cm. 20 m is chosen as the dose rate, which is influenced by only soil because there is a significant decrease in the ambient gamma dose rate.

From the graph, we obtained equation (4);

$$y = 2.34691 \times 10^{-8} \times \exp(-0.19474 \cdot x) + 6.08 \times 10^{-8} \quad (4)$$

Where μ – is the coefficient of absorption in air, x – is the distance. Comparing the exponential indicator with the equation, μ = 0.19474.

Calculation of the annual effective dose and gamma background contribution from buildings

The total gamma background radiation from 0 – 10 m is influenced by both building and soil, hence to find the gamma background influenced by only building, the dose rate at 20 m which is influenced by gamma background radiation from only soil is subtracted from the dose rate from the distance of 0 – 10 m. The gamma dose rate that contributes to the total gamma background radiation ranges from 2.48 – 2.90 nSv/h, which is very small when compared to the total gamma background radiation.

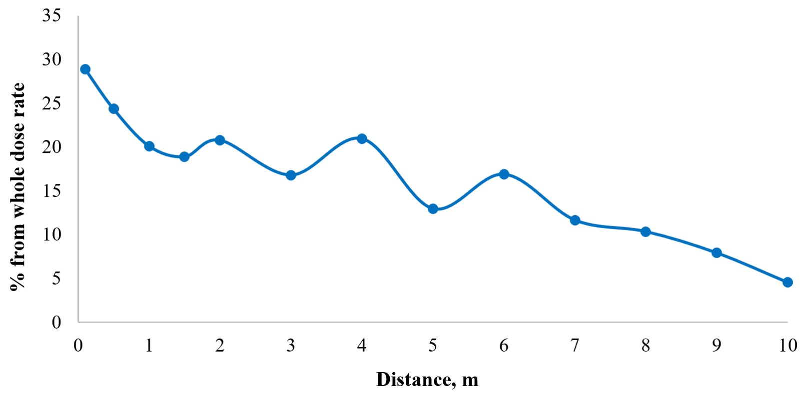

Fig. 5. Contribution of only building to the total gamma background radiation

Figure 5 shows that the contribution of gamma background radiation from the building is between 4 – 29 % of the total gamma background radiation, which is less than 50% of the total gamma background radiation. This shows that most of the gamma background radiation was due to the contribution of the gamma background radiation from the soil. This must be due to the presence of radon and other radionuclides such as thorium and uranium in the soil, which increases gamma background radiation. Also, the house was made from brick which mostly contains materials that do not contribute much to gamma background radiation. As the distance increases, the percentage of gamma background radiation from the building that contributed to the total background radiation decreases because the dose rate decreases proportionally with distance squared.

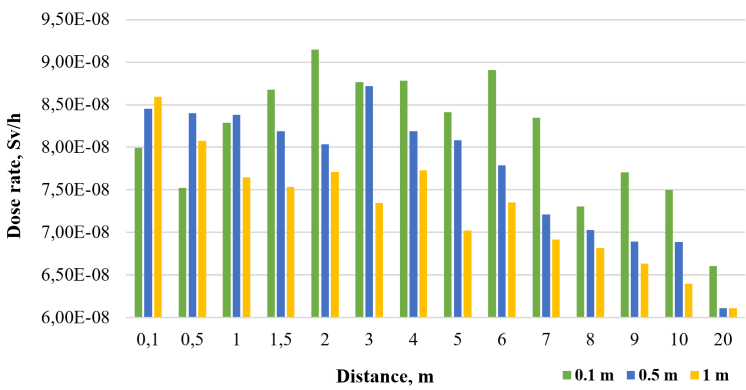

Fig. 6. Gamma dose rate distribution for different height

Figure 6 shows the dose analysis for the measurement taken at different heights of 0.1 m, 0.5 m, and 1 m above the ground. The influence of dose on gamma background radiation increased with increasing distance as we measured further away from the building. The dose also increased with increasing height from above the ground.

The annual effective dose [10] from gamma background radiation was calculated using equation (4).

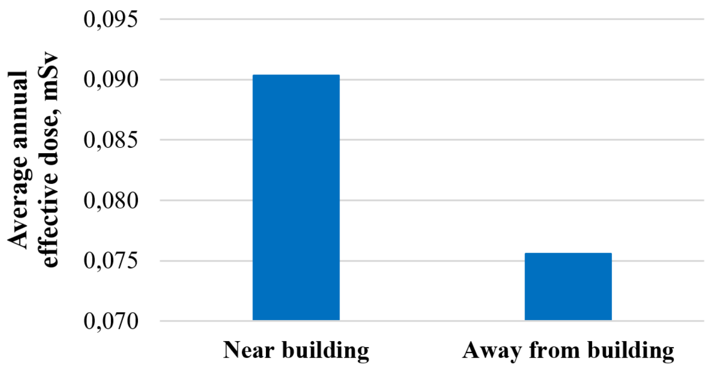

Fig. 7. Average annual effective dose

Figure 7, shows that the average annual effective dose for an adult, who sits near the building at a height of 1 m and a distance within 5 m for a year, is 0.09 mSv [11]. Also, the average annual effective dose of an adult who works far away from the building from a distance of 50 m – 100 m is 0.08 mSv, which are both less than the global level of 0.48 mSv. The average annual effective dose of an adult who sits near the building is higher than an adult who works far away from the building. This is because both the building and the soil contribute to the total dose rate near the building, which is higher than the total dose rate far away from the building, contributed by only soil.

Finding the best place to install a gamma radiation detector

Locating the best place to install a gamma radiation detector is very important because this would help monitor the amount of gamma radiation (dose rate) a person is been exposed to. To find the best location, 3 different height (0.1, 0.5 and 1 m) and 3 different distances (1, 1.5 and 2 m) were considered. The distance of 1 – 2 m was considered because the building was taken as the main source of the gamma radiation and since the same number of photons would be spread out over a big area [12]. Also based on the inverse law the maximum dose rate would be measured near the building than further away from the building which is been backed by experimental readings taken from previous results. The distance of 1 – 2 m would also allow easy monitoring and surveillance of the detector, which might be prone to theft. The average height of a person and the cost of materials were taken into consideration when choosing the height because if the distance was long more materials would be needed to construct the pole required to hang the detector on and this will increase the cost involved.

Figure 8 shows the percentage of the 3 different distances with their corresponding 3 different height. The building was taken as 100% since that was the main source of gamma radiation. From the figure, as we increased the distance away from the building, the dose rate decreased. The dose rate also decreased with increasing height. The best place that would be chosen to install the detector would be a distance and a height of 1.5 m away from the building since that is the average distance that was chosen.

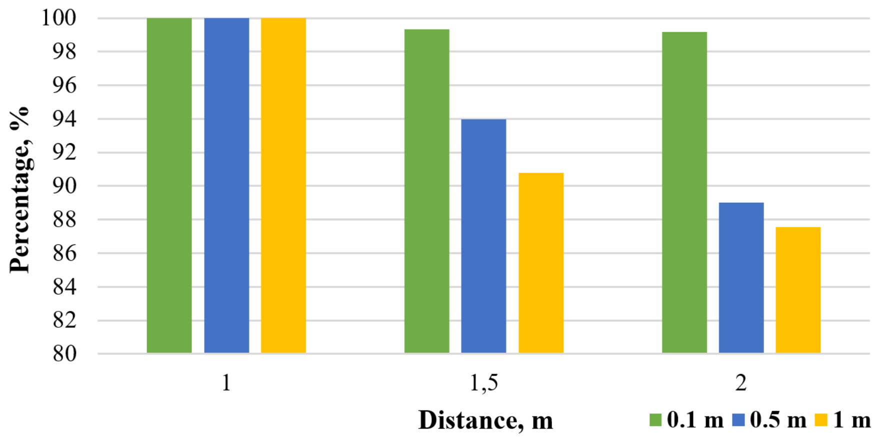

Fig. 8. The percentage of the 3 different distance with their corresponding 3 different height

CONCLUSIONS

The total gamma dose rate near the building decreases with an increase in the distance because the total gamma radiation near the building is contributed from both the soil and the building, which is made from materials that contribute to gamma background radiation. The gamma background radiation contributed by buildings, greatly affects the total gamma background radiation up to a distance of 20 m, where there is a significant decrease in the total gamma background radiation. The total dose rate of gamma background radiation decreases as we measure above the soil at heights of 10 cm, 50 cm, and 1 m. This is explained by the fact that the soil contains radon, a noble gas, which contributes to the increase in the total gamma radiation. Radon first settles into the ground and then diffuses into the environment. This makes the concentration of radon decrease with increasing height above the soil surface, which results in a decrease in the total gamma background radiation with increasing height. The percentage of the building that contributes to the total gamma background radiation is noted to be between 4 – 29% of the total gamma background, which is less than 50%. This shows that most of the background radiation in the environment is contributed by the gamma background radiation in the soil. The annual equivalent dose rate that sits near the building is found to be 0.09 mSv, which is higher than an adult who works far away from the building, found to be 0.08 mSv. Both of these values are less than the global level of the annual effective dose of 0.48 mSv. This shows that a person who sits closer to the building is exposed more to gamma radiation and therefore has to spend fewer hours close to the building. The best place for placing a gamma radiation detector was found to be 1.5 m away from the building and at a height of 1.5 m. Hence, this method for assessing the contribution of gamma background radiation from soil and building as a percentage is optimistic.

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Competing interests. The authors declare that there are no conflicts of interest regarding authorship and publication.

Contribution and Responsibility. All authors contributed to this article. Authors are solely responsible for providing the final version of the article in print. The final version of the manuscript was approved by all authors.

References

[1] Ford J, *Radiation, people and the environment*, 2004.

[2] Shahbazi-Gahrouei Daryoush, Gholami Mehrdad, Setayandeh Samaneh, “A review on natural background radiation”, *Advanced biomedical research*, **2** (2013).

[3] Chamberlain Arthur C., *Radioactive aerosols*, **3**, Cambridge University Press, 2004.

[4] Yakovlev G. A., Yakovleva V. S., “Features of seasonal dynamics of radon isotopes in surface atmosphere”, *Vestnik KRAUNC. Fiz.-mat. nauki*, **31**:2 (2020), 129-138.

[5] Yakovleva V. S., Nagorskiy P. M., Yakovlev G. A., “Technology of radiation monitoring: tracersindicators of dangerous natural and technogenic phenomena”, *Vestnik KRAUNC. Fiz.-mat. nauki*, **14**:3 (2016), 103-113.

[6] *Sources and effects of ionizing radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2008 Report, **1**, 2010.

[7] Medeiros F. HM, Yoshimura E. M., “Influence of soil and buildings on outdoor gamma dose rates in Sao Paulo, Brazil”, *Health physics*, **88**:1 (2005), 65–70.

[8] Amrani D., Tahtat M., “Natural radioactivity in Algerian building materials”, *Applied Radiation and Isotopes*, **54**:4 (2001), 687–689.

[9] Lebedyte M., Butkus D., Morkūnas G., “Variations of the ambient dose equivalent rate in the ground-level air”, *Journal of environmental radioactivity*, **64**:1 (2003), 45–57.

[10] Pashazadeh Ali Mahmoud, et al., “Annual effective dose from environmental gamma radiation in Bushehr city”, *Journal of Environmental Health Science and Engineering*, **12**:1 (2014).

[11] Ghorbanipour Mojtaba, et al, “Health risk assessment of natural background radiation in residents of Khorramabad, Iran”, *Iranian Journal of Medical Physics*, **14**:1 (2017), 23–28.

[12] Nowak Kamila J., Solecki Andrzej T., “Factors affecting background gamma radiation in an urban space”, *Journal of Elementology*, **20**:3 (2015).

УДК 550.35 Научная статья

Влияние зданий на суммарный гамма-фон

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Исследовано влияние зданий на общий гамма-фон. Гамма-фон между кирпичным зданием и полем, находящимся на расстоянии 100 м друг от друга (вдали от влияния других зданий), измерялось с помощью сцинтилляционного детектора. Были проведены измерения мощности амбиентного эквивалента дозы на разной высоте над почвой и на горизонтальном расстоянии от 0,1 м до 100 м с переменным шагом от здания. Был разработан новый подход для оценки вклада от почвы и здания в общий гамма-фон. Было получено, что гамма-излучение, вносимое зданиями, сильно влияет на суммарный гамма-фон на расстоянии до 2 м, на котором наблюдалось значительное уменьшение излучения в общем. Отмечено, что процент вносимого зданием вклада в общий гамма-фон, составляет от 4 до 29%. Это показывает, что большая часть фонового излучения в окружающей среде обеспечивается гамма-излучением почвы. Кроме того, годовая эквивалентная доза, полученная человеком, сидящим рядом со зданием, составила 0,09 мЗв, что выше, чем у взрослого, работающего далеко от здания (0,08 мЗв). Однако оба значения ниже среднемирового. Также было обнаружено, что лучшим местом для установки детектора гамма-излучения будет удаленное на 1,5 м от здания.

Ключевые слова: здания, гамма-фон, мощность амбиентного эквивалентна дозы, почва, годовая эквивалентная доза.

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Конкурирующие интересы. Авторы заявляют, что конфликтов интересов в отношении авторства и публикации нет.

Авторский вклад и ответственность. Все авторы участвовали в написании статьи и полностью несут ответственность за предоставление окончательной версии статьи в печать. Окончательная версия рукописи была одобрена всеми авторами.

Финансирование. Исследование выполнялось без финансовой поддержки фондов.