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Assessment of the contribution of the natural background to the annual effective dose of the staff of the radiology diagnostic rooms at the Saint Petersburg State Pediatric Medical University

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ABSTRACT. ***Introduction.*** Sources of ionizing radiation play a vital role in modern healthcare, finding widespread use in the diagnosis and treatment of diseases. One of the key requirements for the safe use of ionizing radiation sources in medical practice is a high level of professional training of personnel in radiation safety. ***The aim of this study*** was to determine the structure and contribution of natural components to the radiation doses of personnel in the X-ray Departments of the Clinic of the Saint Petersburg State Pediatric Medical University (SPbSPMU). ***Materials and methods.*** The study was conducted in December 2024 at the SPbSPMU Clinic, where the man-made radiation dose of personnel of four departments was determined. Measurements of the ambient dose equivalent rate of gamma radiation were performed with DKS-AT1123 dosimeters in the premises of permanent and temporary stay of Group A personnel. Based on work time recording, the annual radiation doses of personnel from natural sources of ionizing radiation were calculated. The obtained values were compared with individual dosimetric monitoring data to assess the contribution of the natural component to the individual effective dose. Statistical processing was performed using STATISTICA 12 software. ***Results.*** Based on the dosimetric monitoring conducted in the radiation diagnostics and therapy rooms of the Saint Petersburg State Pediatric Medical University Clinic, it was determined that the annual dose from natural sources does not exceed permissible limits. ***Conclusion.*** Based on the results of the radiation-hygienic assessment, recommendations for healthcare workers on the implementation of radiation protection measures were developed, and the need to improve professional training in radiation safety through the development of continuing professional education was emphasized.

KEYWORDS: radiation background, annual effective dose, X-ray department staff, dosimeters, X-ray emission, occupational exposure

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Оценка вклада природного фона в годовую эффективную дозу персонала кабинетов лучевой диагностики клиники Санкт-Петербургского государственного педиатрического медицинского университета

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РЕЗЮМЕ. ***Введение.*** Источники ионизирующего излучения играют важную роль в современном здравоохранении, находя широкое применение в диагностике и лечении заболеваний. Одним из основных условий безопасного применения источников ионизирующего излучения в медицинской практике является высокий уровень профессиональной подготовки персонала в области радиационной безопасности. ***Цель работы*** — определение структуры и вклада природной компоненты в дозы облучения персонала рентгеновских отделений клиники Санкт-Петербургского государственного педиатрического медицинского университета (СПбГПМУ). ***Материалы и методы.*** Исследование проведено в декабре 2024 г. на базе клиники СПбГПМУ, где была определена доза техногенного облучения персонала четырех отделений. Измерения мощности амбиентного эквивалента дозы гамма-излучения выполнялись дозиметрами ДКС-АТ1123 в помещениях постоянного и временного пребывания персонала группы А. На основе хронометража рабочего времени были рассчитаны годовые дозы облучения персонала от природных источников ионизирующего излучения. Полученные значения сравнили с данными индивидуального дозиметрического контроля для оценки вклада природной компоненты в индивидуальную эффективную дозу. Статистическая обработка проведена с помощью программного обеспечения STATISTICA 12. ***Результаты.*** По результатам проведенного дозиметрического контроля в кабинетах лучевой диагностики и терапии клиники СПбГПМУ определили, что годовая доза от природных источников не превышает допустимые значения. ***Заключение.*** На основании результатов радиационно-гигиенической оценки разработаны рекомендации для медицинских работников по внедрению мер радиационной защиты, а также подчеркнута необходимость повышения уровня профессиональной подготовки в области радиационной безопасности посредством совершенствования системы дополнительного профессионального образования.

КЛЮЧЕВЫЕ СЛОВА: радиационный фон, годовая эффективная доза, персонал рентгеновских отделений, дозиметры, рентгеновское излучение, профессиональное облучение

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

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INTRODUCTION

Radiation doses to personnel working with ionizing radiation sources (IRS) consist of two components: external and internal radiation doses from artificial and natural sources. Artificial sources are those with which a person works or an exposure zone where a person is exposed to radiation; natural sources are those that affect a worker while performing their job duties. In accordance with current approaches to ensuring the radiation safety of personnel (workers)[1], dose limits for personnel are established only for artificial radiation. During group and individual dosimetric monitoring (IDM) of personnel, radiation dose values from both artificial and natural radiation are recorded. Thus, current approaches to interpreting radiation monitoring results imply a systematic overestimation of personnel radiation doses. For an objective assessment of artificial radiation doses, it is advisable to account for the contribution of natural background radiation to personnel radiation doses.

Issues related to the proper interpretation of radiation monitoring results for personnel are most relevant for medical staff performing X-ray procedures, particularly regarding the need to subtract the natural background radiation. This category of personnel is among the least exposed of all medical workers classified as Group A[2 3 4] personnel. If the work process is properly organized, stationary radiation shielding is adequately designed and implemented, and personal protective equipment is used, the doses of artificial radiation exposure for this category of workers amount to less than 1 mSv/year (natural background dose values are 1.14 mSv/year (based on ambient equivalent dose rate (AEDR) measurements) and 0.89 mSv/year (using the thermoluminescent dosimeter (TLD) method [1–3]).

Since 2012 [4–6], international practice has required to subtract doses from natural ionizing radiation sources (IRS) from the individual effective dose of personnel. All current international documents on the assessment of occupational radiation exposure levels provide information exclusively on doses from man-made radiation sources [7]. An objective analysis of personnel radiation doses from man-made IRS is necessary to evaluate the effectiveness of radiation protection measures and methods applied at the facility, as well as in domestic practice for the special assessment of working conditions.[5]

The Russian Federation does not subtract the natural background radiation when interpreting individual dosimetric monitoring (IDM) results. Sooner or later, a transition to background subtraction will become necessary[6] due to the need to harmonize domestic regulatory legal acts with the regulatory documents of international organizations in the field of radiation safety [4–6]. The main challenge is to develop a simple and objective method for assessing natural radiation doses that would be specific to each facility where work with ionizing radiation is conducted. It is also necessary to determine in which cases background subtraction should be performed, what value to select for the subtracted background, what method to use for background measurements, and at what

[1] Radiation Safety Standards (NRB-99/2009): Sanitary Rules and Regulations (SanPiN 2.6.1.2523-09). Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor; 2009. Available at: https://spb-institute. ru/upload/iblock/270/270770159d23e4b414abc8cf07cbc5 2f.pdf?ysclid=mgv3v50zme209547980 (accessed: October 17, 2025).

[2] Ibid.

[3] Basic Sanitary Rules for Radiation Safety (OSPORB-99/2010): SP 2.6.1.2612-10. Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor; 2010. Available at: https://spb-institute.ru/upload/iblock/daf/daf8fb0f13fb5d-4fe5829d5bf1ab2a85.pdf?ysclid=mgv40tfasr823676087 (accessed: October 17, 2025).

[4] MR 2.6.1.0257-21.2.6.1. Ionizing radiation, radiation safety. Conducting radiation hygiene certification. Methodological recommendations. Available at: https://mru1.fmba.gov.ru/upload/iblock/c58/dowjqxc8o3nuqrwf0lyxe5p7jsgnq98m/MR-2.6.1.0257_21.pdf?ysclid=mgv4606rrw637674173 (accessed: October 17, 2025).

[5] Order of the Ministry of Labor of the Russian Federation No. 817N dated November 21, 2023, “On the Approval of the Methodology for Conducting a Special Assessment of Working Conditions, the Classification of Harmful and/or Hazardous Occupational Factors, the Form for the Report on the Special Assessment of Working Conditions, and Instructions for Completing It.” Available at: https://normativ.kontur.ru/document?moduleId=1&documentId=461108&ysclid=mggatqjvkr441096518 (accessed: October 7, 2025).

[6] Decree of the President of the Russian Federation No. 585 of October 13, 2018, “On the Approval of the Fundamentals of State Policy in the Field of Ensuring Nuclear and Radiation Safety of the Russian Federation for the Period up to 2025 and Beyond.” Available at: https://base.garant.ru/72075716/ (accessed: December 17, 2025).

stage of measurement it is necessary to perform background subtraction [8].

The simplest method for assessing levels of external natural radiation exposure is to rely on measurements of the ambient equivalent dose rate (AEDR) of gamma radiation in areas where personnel stay. Such measurements are typically conducted when residential, public, and industrial buildings and facilities are put into operation; however, this method has not been applied to radiation monitoring for Group A personnel.

AIM

The aim was to assess the contribution of natural background radiation to the annual effective dose of personnel in the radiology departments of the SPbSPMU clinical hospital.

MATERIALS AND METHODS

The study was conducted in radiology rooms of the emergency, third, and fourth surgical departments, the oncology department, and the Consultative and Diagnostic Center (CDC) of the SPbSPMU. These rooms are located on the first floor of two-, three-, and four-story brick buildings; the walls are brick, and the floors are reinforced concrete. All rooms are equipped with supply and exhaust ventilation.[1]

The study included the following stages:

- identification of rooms for permanent and temporary occupancy by Group A personnel in each of the selected departments;
- conducting a series of gamma-ray radiation measurements using a dosimeter in each room at the end of the workday with radiation sources turned off;
- determining the time spent by individuals classified as Group A personnel in various rooms;
- assessment of external natural gamma-radiation doses for each individual classified as Group A personnel over the course of a year;
- comparison of the IDM results for individuals classified as Group A personnel with the results of external gamma-radiation dose determinations, and determination of the contribution of the natural component.

[1] SanPiN 2.6.1.1192-03 "Hygienic Requirements for the Design and Operation of X-ray Rooms and Equipment and the Conduct of X-ray Examinations." Available at: https://medlicenzor.ru/f/sanpin_2611192-03-rentgen-kabinet.pdf (accessed: October 17, 2025).

AEDR measurements were conducted in accordance with Methodological Guidelines (MG) 2.6.1.2838-11 using DKS-AT1123 dosimeters (Atomtech Production Unit, Republic of Belarus). They were performed by staff members of the P.V. Ramzaev "Research Institute of Radiation Hygiene." All dosimeters had a valid calibration certificate. Measurements were conducted in procedure rooms, control rooms, doctors' offices, and rest rooms. A separate set of measurements was conducted in workwear storage rooms, where work clothing containing personal dosimeters is stored.

The effective doses (ED) for personnel based on the IDM results were taken from the personnel individual radiation dose records for 2024. The IDM was performed by a third-party organization (an accredited radiation monitoring laboratory).

In order to determine working hours and exposure time to natural ionizing radiation at workplaces, a survey of specialists was conducted to establish the specifics of working time tracking.

Personnel radiation doses for 6 hours (a workday) and for 24 hours, taking into account the number of working days in a year, were calculated using the following formulas:

$$X_1=K_1\cdot n_1\cdot h_1/1000=K_1\cdot 1{,}49 \text{ and}$$
$$X_2=K_2\cdot n_2\cdot h_2/1000=K_2\cdot 8{,}76,$$

where $X_{1,2}$ — annual dose due to external gamma radiation from natural sources, mSv;
$K_{1,2}$ — AEDR, μSv/h; n1 — number of working days per year; n_2 — number of days per year; h_1 — number of working hours per day; h_2 — number of hours per day.

Statistical data analysis was performed using STATISTICA 12 software.

RESULTS AND DISCUSSION

The results of AEDR measurements on the premises of SPbSPMU are presented in Figure 1. AEDR values ranged from 107 to 148 nSv/h, and the total measurement uncertainty did not exceed 10%.

The results of AEDR measurements in four departments of the SPbSPMU clinical hospital are presented in Table 1.

The measurement results presented in Figure 1 and Table 1 indicate the absence of radiation anomalies on SPbSPMU premises in the areas where measurements were taken. Natural radiation

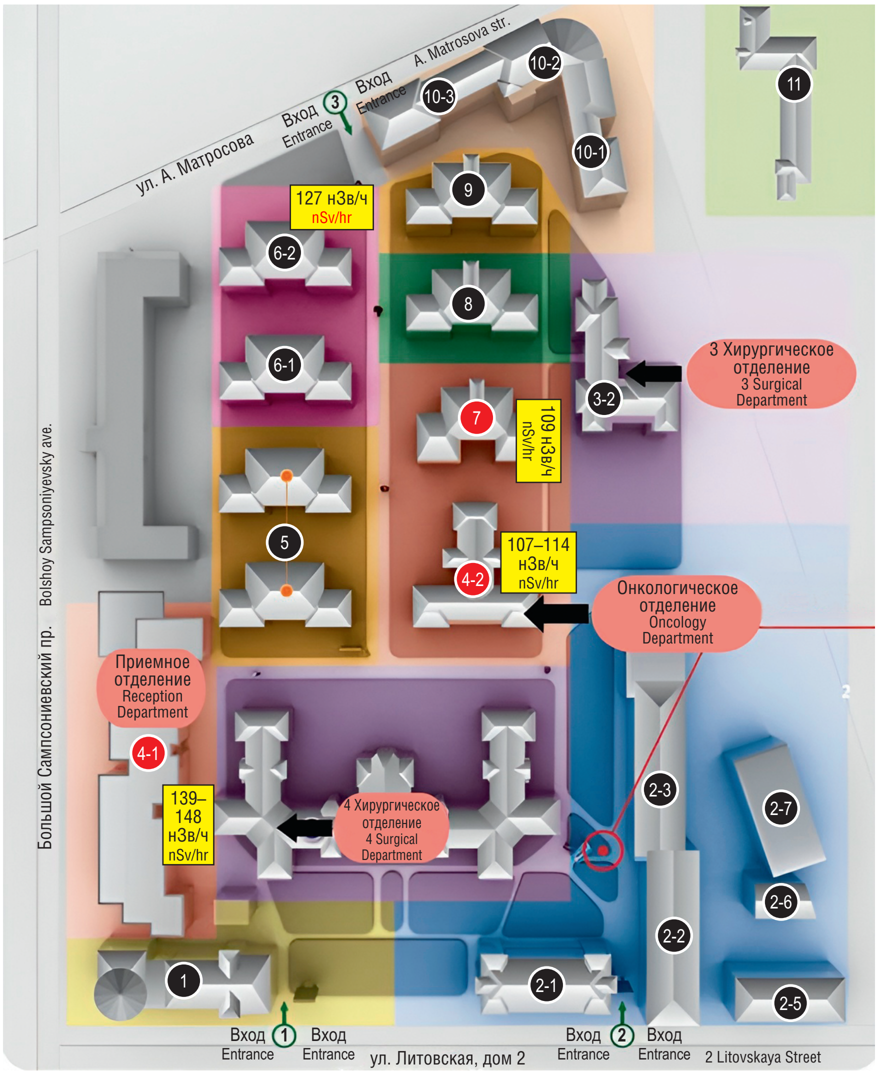

Fig. 1. Dosimetry results on the territory of Saint Petersburg State Pediatric Medical University (the figure is prepared by the authors)

Рис. 1. Результаты дозиметрии на территории Санкт-Петербургского государственного педиатрического медицинского университета (рисунок подготовлен авторами)

levels on the premises and in the departments are uniform, which allows for the subsequent use of weighted average AEDR values to determine the contribution of the natural component to the annual effective dose of personnel.

Annual natural radiation doses were calculated based on a 6-hour workday for staff and 24-hour exposure for dosimeters located in the department offices. The results are presented in Table 2.

Although Group A staff spend only a limited amount of time in the department (no more than 6 hours per day per shift), their personal dosimeters remain in the premises 24 hours a day and are exposed to a uniform dose of ionizing radiation from natural sources.

A comparison was made between the obtained values and data from the personnel's individual radiation dose records. The results of the comparison are presented in Figure 2. The individual annual dose values of 12 employees of the radiology department at SPbSPMU were used: 3 physicians, a nurse, and a laboratory technician from the Diagnostic and Consultation Center; one physician and one nurse each from the emergency, surgical, and oncology departments. The structure of the annual effective dose for staff was calculated assuming round-the-clock exposure of individual dosimeters. One of the orderlies had more than 50% man-made radiation in the annual dose due to long workdays (working two shifts).

As shown in Figure 2, between 0.92 and 1.22 mSv (63% and 77%, respectively) of the annual effective dose for staff is attributable to natural radiation, while the man-made radiation component accounts for 0.31 to 1.48 mSv (37% and 23%, respectively).

Table 1

Value of the natural radiation dose rate distribution by departments

Таблица 1

Значение мощности дозы природного излучения по отделениям

Отделение Department	Рабочее место Workplace	МАЭД±СКО, нЗв/ч ADER±SD, nSv/h
Консультативно-диагностический центр Consultative and diagnostic center	Рабочее место врача 1 Doctor's workplace 1	137±12,5
	Рабочее место врача 2 Doctor's workplace 2	137±12,5
	Рабочее место лаборанта Technician's workplace	137±12,5
	Рабочее место санитара Orderly's workplace	137±12,5
Приемное отделение Admission department	Рабочее место врача Doctor's workplace	143±12,5
	Рабочее место санитара Orderly's workplace	143±12,5
Хирургическое отделение № 3 Surgery 3	Рабочее место врача Doctor's workplace	105±12,5
	Рабочее место санитара Orderly's workplace	105±12,5
Онкологическое отделение Oncology department	Рабочее место врача Doctor's workplace	124±12,5
	Рабочее место санитара Orderly's workplace	124±12,5
Хирургическое отделение № 4 Surgery 4	Рабочее место врача Doctor's workplace	133±12,5
	Рабочее место санитара Orderly's workplace	133±12,5
Среднее для всех отделений Average for all departments		130±12,5

Таблица составлена авторами / The table is prepared by the authors

Note: ADER — ambient gamma dose equivalent rate; SD — Standard Deviation.

Примечание: МАЭД — мощность амбиентного эквивалента дозы гамма-излучения; СКО — среднеквадратичное отклонение.

Table 2

Comparison of values for 6- and 24-hour exposure

Таблица 2

Сравнение значений при 6- и 24-часовом облучении

Сотрудник Staff member	6-часовое облучение, мЗв 6-hour exposure, mSv	24-часовое облучение, мЗв 24-hour exposure, mSv
Врач Doctor	0,31	1,22
Врач Doctor	0,31	1,22
Лаборант Technician	0,31	1,22
Санитар Orderly	0,31	1,22
Врач Doctor	0,31	1,21
Санитар Orderly	0,31	1,21
Врач Doctor	0,23	0,94
Санитар Orderly	0,23	0,94
Врач Doctor	0,23	0,92
Санитар Orderly	0,23	0,92
Врач Doctor	0,15	1,01
Санитар Orderly	0,15	1,01

Таблица составлена авторами / The table is prepared by the authors

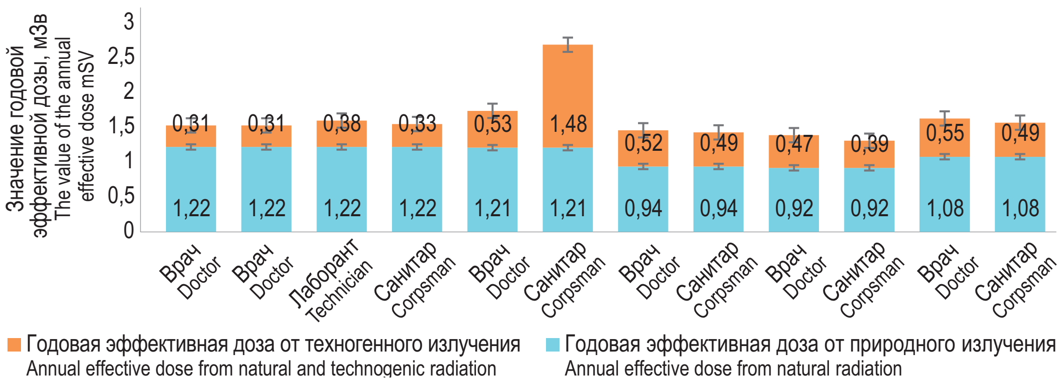

Fig. 2. Contribution of the annual effective dose from natural and technogenic radiation to the annual radiation dose of medical personnel (the figure is prepared by the authors)

Рис. 2. Вклад годовой эффективной дозы от природного и техногенного излучения в годовую дозу облучения медицинского персонала (рисунок подготовлен авторами)

CONCLUSION

The results of the study revealed that:

- the annual dose from natural sources, calculated based on a 6-hour workday and a 5-day workweek, amounted to 0.26±0.06 mSv;
- the annual dose, taking into account 24-hour exposure, was 1.09±0.11 mSv;
- the percentage of background radiation per day for a 6-hour workday and a 5-day workweek was 16±3.8%;
- the percentage of background radiation when accounting for 24-hour exposure was 69±9.3%.

Current levels of man-made radiation exposure for Group A personnel in the examined departments of St. Petersburg State Medical University are extremely low (below the annual dose limit for the general population), indicating that an adequate level of radiation protection for personnel has been achieved.

The proposed methodology is based on dosimetric monitoring and calculation, using a formula to determine how much the natural component contributes to the annual effective dose of personnel at medical organizations working with IRS. It is simple, reproducible, and successfully complements the results of group and individual dosimetric monitoring. The implementation of this methodology will successfully solve the problem of subtracting natural background radiation when interpreting radiation monitoring results.

The study is a pilot project. Further measurements are planned in other medical institutions in St. Petersburg as part of the validation process.

ADDITIONAL INFORMATION

Authors' contribution. A.V. Vodovatov — determination of the main focus of the review, expert evaluation of literature review, research design development; Yu.N. Kapyrina — search for relevant publications, literature analysis, research design development; A.S. Klimenkova — research design development, data processing, writing; O.A. Andzhigaeva — research design development, data processing, writing; V.I. Serova — research design development, data processing, writing; K.K. Panuntseva — determination of the main focus of the review, expert evaluation of literature review, research design development, editing of the review; V.G. Puzyrev — determination of the main focus of the review, expert evaluation of literature review, research design development, editing of the review.

All authors read and approved the final version before publication.

Competing interests. The authors declare that they have no competing interests.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. А.В. Водоватов — определение основной направленности статьи, экспертная оценка списка литературы, разработка дизайна исследования; Ю.Н. Капырина — поиск публикаций по теме, анализ литературы, разработка дизайна исследования; А.С. Клименкова — разработка дизайна исследования, проведение измерений, обработка полученных результатов, написание текста; О.А. Анджигаева — разработка дизайна исследования, проведение измерений, обработка полученных результатов, написание текста; В.И. Серова — разработка дизайна исследования, проведение измерений, обработка полученных результатов, написание текста; К.К. Панунцева — определение основной направленности статьи, экспертная оценка списка литературы, разработка дизайна исследования, редактирование статьи; В.Г. Пузырев — определение основной направленности статьи, экспертная оценка списка литературы, разработка дизайна исследования, редактирование статьи.

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