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ANALYSIS OF PERSONNEL RADIATION DOSES DURING X-RAY PROCEDURES

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Abstract
The article is devoted to the study of the problem of occupational exposure of personnel in healthcare organizations and a comparative assessment of radiation levels. An analysis of 817 individual dose measurement results for personnel in Tashkent healthcare institutions over a 3-year period (2023–2025) was conducted. A comparison of average individual annual effective doses was performed for 4 groups of healthcare workers: X-ray technicians , radiologist, dental radiologists, and members of X-ray surgical teams (surgeons, anesthesiologists, and operating room nurses) working in close proximity to the radiation source. It is shown that the average annual effective dose for the first three groups of healthcare workers is 1.72 mSv . For members of X-ray surgical teams, the analogous value is 3.48 mSv . For the period 2023–2025. The individual annual effective radiation doses of personnel did not exceed the basic dose limits established by SanPiN 0193-06 "Radiation Safety Standards (NRB-2006) and Basic Sanitary Rules for Ensuring Radiation Safety (OSPORB-2006)." The accuracy of effective dose assessment based on individual dose equivalent measurements was also examined.

Keywords: Personnel, medical organization, individual dosimetric monitoring, thermoluminescent method, individual dose equivalent, effective dose.

Introduction

The increasing use of ionizing radiation sources (IRS) in all sectors of the economy, including medicine, leads to an increase in the number of people exposed to man-made sources of ionizing radiation. Addressing the issue of effective radiation protection for personnel and the population of the Republic of Uzbekistan during diagnostic and therapeutic procedures using IRS is an important priority for the

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state [1]. Thus, today, there are 319 radiation-hazardous facilities operating in Tashkent that use ionizing radiation sources and radioactive substances in their activities. Of these, 95% are medical institutions that use X-ray-based research methods: radiography, fluoroscopy, computed tomography, mammography, angiography, etc. In this regard, the number of personnel in Group A medical organizations in Tashkent in 2023 was 746 people, in 2024 - 774 people, in 2025 - 817 people. To ensure safe working conditions for personnel and develop areas for further improvement of radiation safety, it is necessary to understand the patterns of individual dose (ID) formation both at the regional and national levels. In accordance with Law No. 120- II "On Radiation Safety" of August 31, 2000, the radiation hygiene departments and radiology laboratories of the Republican Committee for Sanitary and Epidemiological Welfare and Public Health under the Ministry of Health of the Republic of Uzbekistan are responsible for ensuring the radiation safety of personnel working with ionizing radiation sources. They also carry out state monitoring and accounting of individual doses of medical personnel. This work is carried out in accordance with the following legislative and regulatory documents:
- Constitution of the Republic of Uzbekistan;
- Law of the Republic of Uzbekistan “On the sanitary and epidemiological well-being of the population” No. ЗРУ-393 dated 08.26.2015;
- Law of the Republic of Uzbekistan “On the Use of Atomic Energy for Peaceful Purposes” No. ЗРУ-565 dated 09.09.2019;
- Law of the Republic of Uzbekistan “On Radiation Safety” No. 120-II dated August 30, 2000;
- Law of the Republic of Uzbekistan “On Waste” No. 362-II dated 05.04.2002;
- Decrees, Resolutions and Orders of the President of the Republic of Uzbekistan , Resolutions, orders of the Cabinet of Ministers of the Republic of Uzbekistan , Regulations, SanPiNs, SNiPs, MU, MR and other current documents in the field of radiation safety.

The activities of the service for monitoring the radiation safety of the population are closely linked with the State Committee for Industrial Safety, the Ministry of Emergency Situations, the State Customs Committee, the Ministry of Internal Affairs and other agencies.

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Dosimetric monitoring is conducted in all organizations where work is carried out with sources of ionizing radiation and radioactive substances. Radiation monitoring is carried out by a responsible person within the organization, appointed by order in accordance with current regulatory requirements [2]. X-ray and radiology medical organizations annually submit information on the radiation doses of Group A personnel under normal operating conditions of man-made sources of ionizing radiation to the radiation safety departments of the regional departments of the Service for Sanitary and Epidemiological Welfare and Public Health of the Republic of Uzbekistan. This information is then summarized and transmitted to the Ministry of Health of the Republic of Uzbekistan . This accounting system allows for the recording and analysis of personnel radiation dose data depending on gender, age, and profession over time at the facility, regional, and national levels.

Monitoring occupational exposure is one of the primary objectives of the radiation safety system for personnel. The purpose of monitoring, from a radiation protection perspective, is to verify that working conditions comply with the requirements of standards and regulations and to confirm that personnel radiation safety is adequately ensured and that the man-made source is under control. Another, equally important, objective of monitoring is to monitor personnel radiation doses. Monitoring is necessary for identifying trends in the levels of exposure of various professional groups of personnel, for the long-term planning of measures to limit radiation exposure to personnel, and the databases created within the framework of monitoring programs can form the basis for epidemiological studies and radiation risk assessments [3].

For radiation protection purposes, it is necessary to estimate the individual effective dose of external irradiation of personnel (E) and the individual equivalent doses of irradiation of individual organs and tissues. Since the standardized quantities are not directly measurable, operational quantities, uniquely determined by the physical characteristics of the radiation field, are used [4]. The results of measurements of operational quantities are accepted as a reasonably conservative estimate of the corresponding standardized quantities. The operational value for the external radiation dosimeter is the individual dose equivalent, Hp (d). The value of the parameter d, in mm, which determines the requirements for the individual

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external radiation dosimeter, as well as the location of the dosimeter on the worker's body, are determined by the standardized value for which its equivalent is used [5].

The aim of the study is to differentiate the effective radiation doses of various groups of medical workers working with X-ray equipment based on individual dosimetric monitoring using thermoluminescence dosimetry.

Materials and methods

The paper presents an analysis of the results of monitoring the individual dose equivalent values Hp (10), obtained by thermoluminescence dosimetry (TLD), for various groups of medical personnel working with radiation sources. The initial materials for this study were the results of monitoring the annual individual doses of personnel working with radiation sources in medical organizations in Tashkent. Currently, in Uzbekistan, TLD dosimeters are used to conduct individual dose equivalent monitoring for all category A personnel at radiation-hazardous facilities. Readings from TLDs are taken quarterly, after 3 months from the date of installation of the dosimeters, in the radiological laboratory of the Republican Committee for Sanitary and Epidemiological Welfare and Public Health, since only this laboratory A DVG-02TM thermoluminescent dosimetric unit is available. Thermoluminescent dosimeters are designed to measure the individual dose equivalent of photon radiation Hp (10). The dosimeter consists of a plastic housing housing thermoluminescent detectors. The upgraded DVG-02TM unit enables external gamma and neutron radiation dose measurements. By replacing the detector, it is possible to determine surface doses in facial skin, the lens of the eye, and the skin of the fingers. The unit's reading device is integrated with a PC; a monitor, keyboard, printer, and mouse are connected to it via standard connectors. DVG software (DVG software) was developed specifically for the DVG-02T unit. DVG software processes the thermoluminescence curves (TLC) obtained from thermoluminescent detectors. The program enables automatic peak detection, selection of integration boundaries, background subtraction if necessary, and dosimetric peak approximation in cases where the CTV is a superposition of several peaks from which only one dosimetric peak needs to be isolated. DVG software stores calibration and dosimetric information for each dosimeter,

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including its type, a symbol describing the dosimeter configuration (type, number, and placement of detectors), and its identification number.

The IDC includes annealing (to remove residual information from the detectors), exposure of the dosimeters to the fields of the ionizing radiation source, reading the light sum (proportional to the accumulated dose) using a TLD reader, and subtracting the detector's own background from the obtained result.

To determine the calibration coefficient, all detectors are pre-irradiated in a standard radiation field of cesium-137 or cobalt-60 radionuclide sources with the same dose ranging from 1 to 10 mSv . The working group of detectors is then sorted by sensitivity (in this case, (K = 0.12 mSv / nC) ± 10%).

The groups of medical personnel in our research work were selected in accordance with their working conditions:

– 1st group: X-ray technicians – work behind protection and, accordingly, receive small dose loads;

– 2nd group: radiologists of dental clinics – they work with low-dose equipment, so they also have a low risk of overexposure ;

– Group 3: radiologists whose duties may include conducting X-ray examinations and, therefore, there is a risk of receiving higher doses;

– Group 4: members of X-ray surgical teams (surgeons, anesthesiologists, operating room nurses) – perform operations under X-ray control, so they can receive significantly higher doses than all other categories of personnel.

As of December 1, 2025, there are 319 medical organizations operating in Tashkent that use ionizing radiation sources. These organizations employ 649 Category A personnel, including 337 X -ray technicians , 325 radiologists, 114 dental radiologists, and 41 members of X-ray surgical teams.

The information used in this study was obtained from the research and testing radiology laboratory of the Center for the Development of Professional Qualifications of Medical Workers of the Ministry of Health of the Republic of Uzbekistan over a three-year period (2023–2025). An analysis of 817 individual dose measurements was conducted.

Results and Discussion

An analysis of the Hp (10) measurement results was conducted for various professional groups of Tashkent medical personnel exposed to X-rays, according

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to the reporting forms submitted annually to the Ministry of Health of the Republic of Uzbekistan . The results are presented in the table.

Table Minimum and maximum values of individual annual effective doses of X-ray radiation for medical workers

Professional group	Annual effective dose, mSv	
	minimal	maximum
x-ray technicians	1.12	2.84
radiologists of dental clinics	0.97	2.28
X-ray technicians who perform X-rays and fluoroscopy	1.37	3.25
members of X-ray surgical teams	2.24	7.27

To preliminarily assess differences in radiation exposure levels among personnel performing various procedures, data obtained during the IDC were analyzed. The frequency distributions of effective doses received by personnel in four occupational groups were also compared.

The resulting distributions were approximated by lognormal distributions of the obtained effective doses [6]. In comparison with the 1st, 2nd and 3rd groups, a statistically significant difference exists for the 4th group, while the differences in the average dose over 3 years for the 1st, 2nd and 3rd groups are not statistically significantly different. Thus, the average frequency distribution of annual Hp (10) values over 3 years for X-ray lab technicians was 1.59 mSv (max = 2.84 mSv ; min = 1.12 mSv). The average frequency distribution of annual Hp (10) values over 3 years for dental radiologists was 1.17 mSv (max = 2.28 mSv ; min = 0.97 mSv). The average frequency distribution of annual Hp (10) values over 3 years for radiologists was 1.95 mSv (max = 3.25 mSv ; min = 1.37 mSv). The average frequency distribution of annual Hp (10) values over 3 years for surgeons, anesthesiologists, and operating room nurses was 3.48 mSv (max = 7.27 mSv ; min = 2.24 mSv).

The absence of statistically significant differences in average doses between groups 1, 2, and 3 (radiographers , radiologists, and dental radiologists), despite their different job responsibilities, likely indicates that their exposure conditions are similar. Therefore, in future analyses of annual effective doses, these specialists could be grouped together.

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The figure shows the average values of annual effective radiation doses to personnel for 2023-2025.

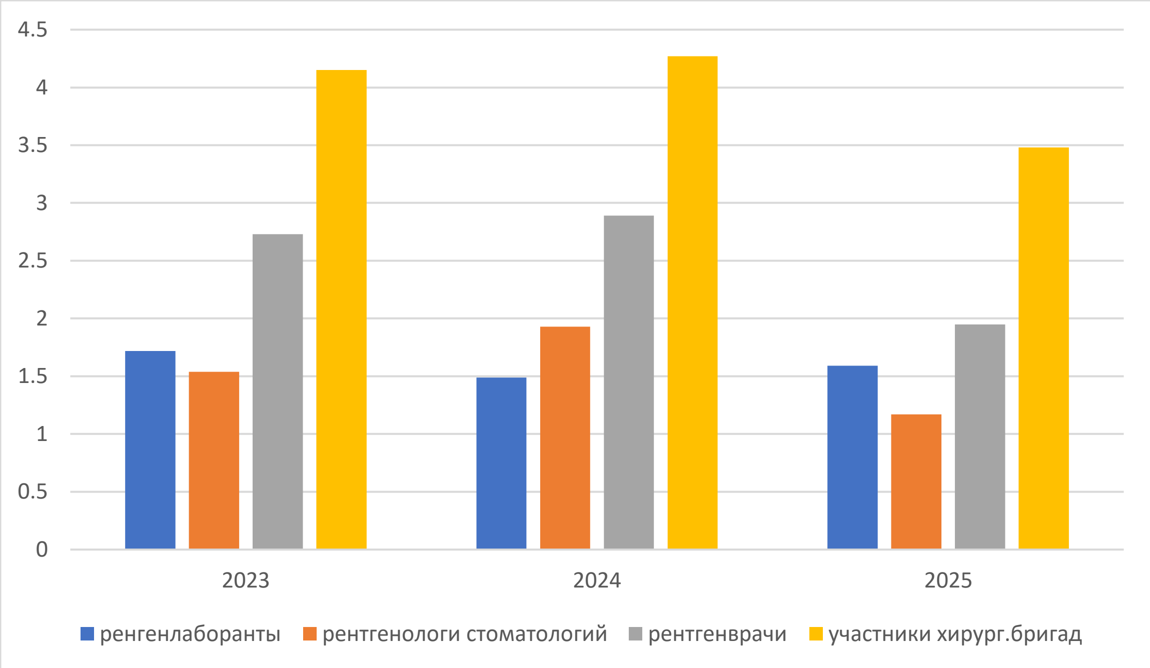

Fig. 1. Average annual effective radiation doses to medical workers operating X-ray equipment for 2023–2025.

Based on the above distributions, it was established that the occupational radiation doses of specialists working under X-ray monitoring are several times higher (2-3 times). The results of the study show that the overwhelming majority of employees from among the Group A personnel receive doses that, on average, do not exceed 5-7% of the dose limit (DL) (1.17 mSv), with the exception of personnel of X-ray surgical teams (group 4), for whom this value is 17% of the DL (3.48 mSv). Moreover, the maximum individual doses do not approach the DL for Group A personnel and in some cases exceed the DL for Group B personnel. It should be noted that in accordance with the requirements of paragraph 6.89. SanPiN No. 0194-06 classifies Group 4 specialists (dentists, surgeons, urologists, surgical assistants, traumatologists, and others) as Group B personnel and therefore should not be exposed to a dose exceeding 5 mSv per year. For medical personnel located outside the source's shielding (control room, photo lab, and adjacent rooms), body irradiation is fairly uniform, and a single personal dosimeter placed on the body's

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surface (e.g., in the breast pocket of a gown) is sufficient to estimate the effective dose using its readings and the appropriate conversion factor. Other medical personnel working in the procedure room, as well as medical personnel performing specialized X-ray examinations, are required by the nature of their work to be near the patient, i.e., in close proximity to the X-ray source. Body irradiation for this category of personnel is significantly uneven. According to the data of phantom and natural measurements, on the front surface of the body these workers have The dose difference is more than 10-fold, and the dose gradient within the body is significantly greater. The distribution of surface and depth doses also depends on the additional shielding of the body with a protective apron. In this case, to accurately assess the individual dose, it is necessary to use two or more dosimeters placed on the worker's body.

A section of the report by the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units (ICRU) [10] is devoted to studying the relationship between the value of Hp (10), obtained by instrumental methods, and the effective dose. The report, in particular, presents the energy dependence of the ratio of the effective dose (E) to the individual dose equivalent Hp (10) for monoenergetic photons.

It is clear that the ratios vary widely depending on the irradiation geometry and photon energy, but always remain less than unity. Therefore, the effective dose estimate based on the individual dose equivalent measurement is conservative. The degree of conservatism is determined by both the spectral distribution of the active photon radiation and the energy dependence of the detector sensitivity.

It should be noted that additional uncertainties in the results of the IDC are caused by subjective reasons.

First, after several years of ensuring that the doses received are not alarming, some monitored individuals stop wearing dosimeters. In such cases, background radiation levels in the work areas are measured instead of individual doses.

Secondly, some employees, fearing penalties from regulatory authorities for failure to comply with radiation safety measures, do not always wear personal dosimeters during X-ray and radiological procedures.

Thirdly, there are cases when very curious employees, on the contrary, leave a dosimeter near the source to check the quality of the information reading.

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The current situation must be changed through explanatory work and disciplinary measures.

Conclusions

Databases do not allow for detailed distribution of individual doses for individual professions within an entire professional group, particularly medical personnel. The study shows that the average individual annual radiation doses for surgeons, anesthesiologists, and operating room nurses working in close proximity to X-ray sources exceed the radiation doses for medical personnel in other professions by 3-5 times.

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