METHODOLOGICAL SUPPORT OF ACTIVITIES ON DECOMMISSIONING THE NUCLEAR FACILITIES

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Personnel safety is a priority when decommissioning obsolete nuclear facilities. The study was aimed to develop the methodological basis for the medical and sanitary support of the nuclear industry enterprise personnel radiation safety during the nuclear legacy elimination on the example of Siberian Chemical Plant (SCP, Seversk). The study involved the data of the SCP employees' medical and dosimetric register containing information about all cases of death (with an indication of the cause) of former and current employees of the enterprise. The study results were used to justify selection of the area for development of scientific and methodological support of activities in the field of medical and sanitary support of radiation safety during the nuclear legacy elimination. Death rates and the risk of dying from cancer of certain localizations (trachea, bronchi, lung, skin, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands) in the nuclear industry enterprise employees were assessed. The directions for improving the medical support of the nuclear enterprise employees and the population of the surveillance zones during the nuclear legacy elimination were defined. The findings will make it possible to adjust the medical support of the nuclear industry enterprise employees in order to extend their working longevity, as well as to reduce the adverse radiation-induced health effects in people engaged in the nuclear legacy elimination.

Keywords: nuclear legacy, radiation safety, nuclear industry enterprise, personnel

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МЕТОДИЧЕСКОЕ СОПРОВОЖДЕНИЕ РАБОТ ПО ВЫВОДУ ИЗ ЭКСПЛУАТАЦИИ ОБЪЕКТОВ АТОМНОЙ ОТРАСЛИ

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Безопасность персонала является приоритетом при выводе из эксплуатации устаревших объектов атомной отрасли. Целью исследования было разработать методические основы медико-санитарного обеспечения радиационной безопасности персонала предприятия атомной отрасли при ликвидации ядерного наследия на примере Сибирского химического комбината (СХК) г. Северск. Исследование проведено на основании сведений медико-дозиметрического регистра персонала СХК, содержащего информацию обо всех случаях смерти (с указанием причины) бывших и действующих работников предприятия. В результате работы обоснован выбор территории для разработки научно-методического сопровождения работ в области медико-санитарного обеспечения радиационной безопасности при ликвидации объектов ядерного наследия. Проанализированы показатели смертности населения выбранной территории и риски смертности персонала предприятия атомной индустрии вследствие злокачественных новообразований некоторых локализаций (трахея, бронхи, легкое, кожа, желудок, толстая кишка, лимфоидной, кроветворной и родственных им тканей, молочная и предстательная железы). Определены направления совершенствования медицинского обеспечения персонала предприятия атомной индустрии и населения зон наблюдения при ликвидации ядерного наследия. Полученные данные позволят скорректировать медицинское сопровождение персонала предприятия атомной отрасли с целью продления трудового долголетия работников, а также снизить негативные радиационно обусловленные последствия на здоровье людей, задействованных в ликвидации объектов ядерного наследия.

Ключевые слова: ядерное наследие, радиационная безопасность, предприятие атомной индустрии, персонал

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Over the past few decades, the issue of decomissioning obsolete factories and nuclear facilities that have reached the end of their service life is becoming more and more urgent due to rapid development of nuclear industry in Russia. When doing such work, ensuring the safety of personnel working at these enterprises, as well as ensuring the safety of the population and environment in the areas where the enterprises are located is one of the priorities declared by the Rosatom State Corporation [1].

Some enterprises of the Russian nuclear industry have been functioning for more than 60 years, these move closer to inevitable scheduled decomissioning. Over more than 75 years of the development of domestic nuclear power, the technologies, equipment and types of fuel have changed considerably, that is why modernization of the existing nuclear enterprises is sometimes impossible. In this regard, the problem arises of the sheduled elimination of the nuclear legacy created at various stages of the nuclear industry development, including elimination with the possibility to reuse these territories for construction of new infrastructure nuclear facilities. This challenging task can be accomplished only through bringing together specialists from various fields (engineers, ecologists, biologists, etc.) and through preliminary development of the evidence-based methodological support taking into account the features of the nuclear legacy to be eliminated [1, 2].

Medical and sanitary support of radiation safety of the eliminated nuclear industry enterprise employees and the population of the surveillance zones is one of the most important activities preceding safe decommissioning of nuclear facilities [1].

Scientific and methodological support of activities aimed at ensuring radiation safety during decomissioning of nuclear facilities requires the assessment of the ionizing radiation (IR) exposure biomedical effects on the personnel of nuclear enterprises, as well as the estimation of radiogenic risks in employees of these enterprises. Scientific and methodological support should be developed based on the production features (technology type, radionuclide spectrum, radiation type, etc.) [2, 3].

In each specific case, the Medical Dosimetric Registry (MDR) of the nucler enterprise employees and the population of adjacent areas together with the data of organizations engaged in monitoring of the conditions of manufacturing process in the main facilities of the enterprise and the employees' health should be used as a source of specific information for such studies [4].

Scientific and methodological support of activities on the nuclear legacy elimination will make it possible to define the major biomedical health effects in the employees engaged in decommissioning of nuclear facilities and to determine a set of measures for extension of their working longevity [3].

At the current phase of the Russian nuclear industry development, given the good progress in radiation safety that had been achieved over the recent years, the focus should be placed on assessing the effects of IR (for example, risk of cancer) involving accumulation of the total external dose (TED) of no more than 100 mSv [1].

The results of numerous epidemiology studies do not allow an unambiguous conclusion about the increased risk of cancer or death from cancer in people who are exposed to IR from man-made sources at work. Some researchers have managed to reveal the increased risk of dying from cancer in the nuclear facility employees [2–4], while other researchers point out that there is no increase in the relative risk of cancer or dying from cancer in employees of such production facilities [5–7].

Methodological support of activities aimed at nuclear legacy elimination requires implementation of the high-tech methods for continuous public health monitoring aimed at identification of the radiation exposure health effects in employees engaged in the nuclear legacy decommissioning, for example, implementation of the automated health monitoring system for the registered population, creation and management of the decommissioned nuclear facility employees' MDR.

The study was aimed to develop the methodological basis for the medical and sanitary suport of the nuclear industry enterprise personnel radiation safety during the nuclear legacy elimination on the example of Siberian Chemical Plant (SCP, Seversk).

METHODS

It is impossible to obtain the evidence-based study results without the use of appropriate research method, i.e. without the correct selection of the objects and methods of research. While the research methods and interim mathematical tools are generally well known and easy to choose (in most cases, these are epidemiologic methods used to assess the risk of the stochastic effects induced by the radiation hazardous facility personnel exposure to IR, primarily of the malignant neoplasms), the selection of object and, therefore, the research territory, is a challenging practical task. The research object and the area where the object is located should meet the following requirements.

1. The research object (nuclear industry enterprise) should have the longest possible history of trouble-free operation; decommissioning of such objects that should be performed on a scheduled basis requires appropriate scientific and methodological support. In case the object has a history of accidents associated with the release of radionuclides into the environment, "accidental" exposure of the personnel and the population of adjacent areas, it is necessary to develop the qualitatively different scientific and methodological support.

2. The development of the mentioned above scientific and methodological support is not possible without using the MDR of the enterprise employees and the population of the surveillance zone taking into account the occupational doses and all cases of cancer. In turn, full maintenance of MDR is possible only in the administratively closed territories, where only one medical institution provides a centralized medical support to the radiation hazardous facility personnel and the population of the surveillance zones.

Based on the above, the Closed Administrative-Territorial Unit (CATU) Seversk is the optimal platform for the development of methodological support for the scheduled decommissioning of nuclear legacy. CATU Seversk is formed around the city of Seversk, where SCP is a city-forming enterprise. The first facilities of SCP (for example, sublimation plant and separation plant) were commissioned in 1953. Over more than 60 years of SCP operation no major accidents resulting in the radionuclide release into the environment were reported. The most notable radiation accident occurred in 1993 at the SCP radiochemical plant. The accident was assigned level three according to the seven-point international radiological event scale.

Medical support of the CATU Seversk population (105,238 people as of 2022), including the SCP employees, is provided by one large medical institution, the Federal Siberian Research Clinical Centre of FMBA of Russia (FSRCC).

The SCP employees' MDR was created by the Seversk Biophysical Research Center of FMBA of Russia (SBRC). The MDR database contains up-to-date information about all employees who ever worked at the SCP, the data about all cases of death (with an indication of the cause) of the former and current SCP employees in CATU Seversk, and the data about the major socially significant non-communicable diseases in SCP employees.

The cohort of SCP employees included all employees (regardless of the type of production) who were hired between 1 January 1950 and 31 December 2020 and worked at the SCP for at least one year.

The SCP structure includes the main and auxiliary production facilities (MP and AP, respectively).

The MP facilities of SCP include the reactor (RF), radiochemistry (RCF), plutonium (PF), separation (SF) facilities, and sublimation plant (SP).

Table 1. Characteristics of the cohort of SCP employees hired between 01 January 1950 and 31 December 2019

Indicator	Gender	RF	RCF	PF	SF	SP	AP
Total number of employees	M	6651	5272	7569	4935	3581	21,373
	F	1323	1115	2267	1492	1101	8766
Number of employees with the defined vital status	M	5493	4454	6561	3389	2477	13,343
	F	1165	1019	2120	1143	865	6643
Number of employees who died from cancer	M	418	286	456	300	226	1312
	F	101	80	171	103	79	579
Number of employees who were provided personal dosimetry due to external exposure	M	5171	4632	3 254	1113	1935	2043
	F	710	802	832	309	487	847
Number of employees who were provided personal dosimetry due to internal exposure	M	86	1990	3 491	534	1039	163
	F	14	441	1 100	270	322	121

The employees of four production facilities (RCF, PF, SF, and SP) are exposed mainly to the combination radiation, while the RF employees are exposed to external radiation only and can be used as a control group when assessing the contribution of internal exposure to radiation-induced effects.

Currently, the MDR database contains the following information about the SCC employees:

– total number of the SCP employees hired since 1950 in accordance with the production type (it should be emphasized that information about all the SCP employees registered by the enterprise Human Resources departments for the whole period of the combine activity has been added to the database since the moment of the MDR creation; this approach makes it possible to form various control groups in accordance with the broad spectrum of scientific tasks);

– personal radiation doses and doses accumulated over time;

– number of deceased SCP employees;

– SCP employees who developed cancer.

All available data is stored electronically and in the form of the archived hard copies.

Table 1 contains information about the employees hired by the SCP MP facilities in 1950–2019.

Tables 2 and 3 present the demographic characteristics of the CATU Seversk population for the period of 1970–2019.

In 1970–2019, the total population (all age groups) of CATU Seversk increased, along with the adult population. Most notably, the number of people over the age of 60 dramatically increased. At the same time, the share of the child population significantly decreased: from 29.5% in 1970–1974 гг. To 15.8% in 2015–2019. The share of males in the population decreased from 48.6% in 1970–1974 to 46.3% in 2015–2019.

Birth rate significantly decreased and mortality increased during the observation period. This resulted in the natural population decline. Changes in the demographic structure of the population, in particular, population ageing, was the cause of the above processes. At the same time, the population life expectancy significantly increased.

Indicators that have been used in the study and information sources for calculation of these indicators are provided in Table 4.

The risk of dying from cancer in the SCP employees was calculated based on the standardized relative risk (SRR).

SRR was calculated in accordance with the following formula:

$$SRR = \frac{A}{E}$$

where A was the actual number of the disease cases or deaths; E was the expected number of the disease cases or deaths .

The lower and upper limits of the SRR 95% confidence interval were calculated in accordance with the following formulae:

$$LL = SRR \times (1 - \frac{1{,}96}{2 \times \sqrt{A}})^2$$

$$UL = SRR \times (1 - \frac{1{,}96}{2 \times \sqrt{A+1}})^2 \times \frac{A+1}{A}$$

where UL was the upper limit and LL was the lower limit.

It was believed that the incidence in the studied group was significantly higher than that in the comparison group when the lower limit of the SRR confidence interval exceeded 1.

To estimate the relationship between the SSR and the increase in TED, we devided the employees into subgroups with various TED values. The indicators of incidence (or mortality) among the SCP employees with no reported exposure doses or employees who never contacted with the man-made radiation sources at work were used as a comparison group (standard). The direct standardization method was used, age stratification was not applied. The calculations were performed twice: first for the dose ranges with the clearly defined lower and upper TED limits (0–20 mSv, 20–50 mSv, 50–100 mSv, 100–150 mSv,

Table 2. Demographic characteristic of the CATU Seversk adult population in the years 1970–2019

Category of the population	Range within the studied period, years							
	1970–1974	1980–1984	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Overall population	87 121 ± 2302.0	97 763.2 ± 1310.1	109 230.0 ± 1580.6	111 701.4 ± 344.2	110 816.4 ± 1732.9	109 949.7 ± 3500.7	115 511.1 ± 750.0	113 728.8 ± 861.5
Adults	57 019.3 ± 1792.0	68 548.4 ± 965.9	78 609.4 ± 2048.1	84 024.0 ± 1667.0	88 255.6 ± 695.8	91 036.6 ± 3313.3	95 679.0 ± 674.1	92 716.8 ± 909.1
People over the age of 60	4140.1 ± 268.9	5 724.3 ± 254.9	11 402.4 ± 1117.8	15 462.8 ± 1592.5	19 223.0 ± 486.3	20 021.3 ± 1236.4	21 335.7 ± 5821.3	26 783.8 ± 1207.7
Men of working age	27 252.9 ± 775.9	30 946.1 ± 882.1	33 790.4 ± 661.9	35 095.2 ± 320.0	35 282.6 ± 208.0	35 919.0 ± 996.5	36 210.6 ± 512.1	33 599.9 ± 754.1
Women of working age	27 480.3 ± 551.9	29 670.0 ± 877.1	32 743.2 ± 224.3	33 029.4 ± 697.1	34 487.2 ± 557.2	33 709.9 ± 816.6	33 207.0 ±1006.2	29 699.6 ± 862.9

Table 3. Major demographic characteristics of the CATU Seversk population in 1970–2019 (per 1000 population)

Indicator	Range within the studied period, years							
	1970–1974	1980–1984	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Birth rate	18.7 ± 1.7	16.9 ± 0.9	10.6 ± 2.1	8.1 ± 0.4	8.5 ± 0.2	9.6 ± 1.0	10.9 ± 0.3	9.4 ± 1.5
Mortality	3.8 ± 0.1	5.7 ± 0.3	8.9 ± 2.1	10.2 ± 0.4	12.1 ± 0.9	12.2 ± 0.6	11.9 ± 0.4	12.5 ± 0.2
Natural increase	14.9 ± 1.8	11.2 ± 0.7	1.8 ± 4.2	-2.1 ± 0.5	-3.6 ± 0.8	-2.6 ± 1.1	-1.1 ± 0.4	-3.1 ± 0.2
Life expectancy, years	72.46 ± 0.48	71.18 ± 0.55	68.67 ± 2.89	68.60 ± 1.36	68.44 ± 0.88	70.89 ± 0.38	73.25 ± 0.60	74.25 ± 0.63

150–200 mSv, 200–300 mSv, 300–500 mSv, and 500–1000 mSv), then for broader ranges in which only the lower limit was defined (> 0 mSv, > 100 mSv, > 200 mSv, > 300 mSv, > 500 mSv), since the range expansion (and, therefore, the increase of person years of observation) increased the statistical significance of the results.

RESULTS

Information about the death rates caused by cancer affecting bronchi, trachea, lungs, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands, skin among male and female populations of CATU Seversk in 1970–2019 is provided in Tables 5 and 6.

The increase in death rates caused by malignant neoplasms of the stomach, colon, bronchi, lung, and prostate gland among male population of CATU Seversk was observed during the studied period (Table 5).

The same trend was observed among females (including death rates caused by breast cancer); the exception were the death rates caused by malignant neoplasms of the stomach that surpassed the high recorded in 2005–2009 and dropped to 25.4 cases per 100,000 population by 2015–2019 (Table 6).

Tables 7 and 8 show the SRR of dying from cancer affecting trachea, bronchi, lungs, skin, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands, in relation to the TED values of the SCP employees for the period between 01 January 1970 and 31 December 2019. TED means the external effective dose absorbed by the employee during the entire period of working at the nuclear industry enterprise.

The analysis did not take into account the employees' age and the calendar time of observation due to the relatively small sample size.

The cases of cancer affecting the digestive organs (stomach and colon), respiratory organs (trachea, bronchi, lung), skin, organs of the male reproductive system (prostate gland), lymphoid, hematopoietic and related tissues among male SCP employees were analyzed. Malignant neoplasms of these organs and tissues were selected because of the fact that these cancer localizations were most common among male population of CATU Seversk not exposed to the man-made IR.

The assessed range covers "low" IR doses (< 100 mSv) that are typical for normal working conditions at modern nuclear enterprises and "medium" IR doses (< 1 Sv) that become possible during radiation emergencies at the nuclear industry enterprises.

Male SCP employees who have been exposed to IR at work with the TED values of 200–1000 mSv have a higher SRR of dying from prostate cancer (Table 4).

The cases of cancer affecting breast, digestive organs (stomach and colon), respiratory organs (trachea, bronchi, lung), skin, lymphoid, hematopoietic and related tissues among female SCP employees were also assessed. Malignant neoplasms of these organs and tissues were selected because of the fact that these cancer localizations were most common among female population of CATU Seversk not exposed to the man-made IR.

Statistical accuracy of the data on female employees is lower than that of the data on male employees due to small sample size resulting from the significantly lower number of women engaged with the IR sources.

The lack of data on some cancer localizations (for example, trachea, bronchi, lung, skin, lymphoid, hematopoietic and related tissues) in female employees exposed to "medium" IR doses is due to the extremely small sample size that is insufficient for statistical analysis.

Female SCP employees with the TED values reaching 100–150 mSv have the increased SRR of dying from malignant neoplasms of trachea, bronchi, lung, stomach, colon, skin, breast, and lymphoid, hematopoietic and related tissues.

It is especially worth noting that the SRR of dying from malignant neoplasms of trachea, bronchi, lung, and breast is increased among female employees with the TED values of 0–20 mSv (Table 8).

Medical support of employees during elimination of nuclear legacy should involve three phases.

Phase one: defining health risk factors for the described population.

Identification of the set of risk factors includes the following:

– assessment of demographics (birth rate, mortality, rate of natural increase), life expectancy, and disability rate in the studied population;

– assessment of morbidity patterns in the studied population and identification of the most prevalent disorders;

Table 4. Indicators and information sources used during the study

Studied indicator	Information source
Cancer mortality in the CATU Seversk population in 1970–2019	Information obtained from: – Territorial unit of the Federal State Statistics Service, Tomsk Region (Tomskstat); – Federal Siberian Research Clinical Centre of FMBA of Russia; – database of the regional MDR of the CATU Seversk population and SCP employees containing the up-to-date information about all cases of death from cancers of the main localizations (trachea, bronchi, lung, skin, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands) in CATU Seversk in 1970–2019
Risk of dying from cancer in the nuclear industry enterprise employees between 01 January 1970 and 31 December 2019	The data obtained from the database of the regional MDR of the CATU Seversk population and SCC employees containing the up-to-date information about all cases of death from cancers of the main localizations (trachea, bronchi, lung, skin, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands) in SCP employees in 1970–2019

Table 5. Death rates caused by cancer among adult male population of CATU Seversk in 1970–2019 (per 100,000 population; group average)

Cancer localization (ICD-10 code)	Range within the studied period, years									
	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Stomach (C16)	19	22.4	20.5	19	18.4	25.9	38.3	44	43.1	24.6
Colon (C18)	0	0	2.2	10.2	14.9	12.2	14.3	22.4	26	26.3
Trachea (C33)	0	0	0	0	0.7	1.5	0.8	1.9	1.9	0.8
Bronchi and lung (C34)	11.2	10.2	36.1	50.8	65.7	80	75.6	80.1	70	99
Skin (C43–44)	0	0	1	2	0.8	2.6	2.8	2.9	3.7	2.8
Prostate gland (C61)	2.3	1.7	0.5	0.7	6	8.7	14.3	19.8	24.6	29.3
Lymphoid, hematopoietic and related tissues (C81–96)	5.3	6	9.2	8.4	11	13.2	20.8	9.5	18.3	25.2

– identification of the risk factors and determination of the potentially modifiable risk factors, such as social-economic, behavioral, medical-organizational, and technogenic factors.

Phase two: formulation of proposals to manage the most common disorders and risk factors identified in the population. Thus, our findings show that the main focus should be on cancer prevention and treatment when developing the strategy for medical support of employees engaged in the activities on the nuclear legacy decommissioning.

Phase three: development of the strategy for medical support of employees engaged in the activities on the nuclear legacy decommissioning by adjustment of the existing strategy based on the new information about the health status of the studied population (demographics, data on morbidity and disability rates) and risk factors in the population.

According to the study, male SCP employees have a high SRR of dying from prostate cancer, while female employees have a high SRR of dying from malignant neoplasms of trachea, bronchi, lung, stomach, colon, skin, breast, lymphoid, hematopoietic and related tissues.

The strategy for medical support of employees engaged in the activities on the nuclear legacy decommissioning should be developed based on the above data in accordance with the goals and outputs of the Healthcare national project and the Fight Against Oncological Diseases federal project. In particular, it is necessary to define the list of additional instrumental and laboratory tests for diagnosis of cancer to be used during the routine medical check-ups in employees engaged in the nuclear legacy elimination (primarily based on the cancer localizations identified).

According to the Fight Against Oncological Diseases federal project, the death rate caused by cancer in the population should not exceed 185 cases per 100,000 population by the year 2024. It is appropriate to consider these values as the target indicators when developing the strategy for health protection of employees engaged in the activities on the nuclear legacy decommissioning.

DISCUSSION

Organizing activities on decomissioning the nuclear facilities that have reached the end of their service life is one of the areas of nuclear safety. In turn, safe decomissioning of the nuclear facility is impossible without medical and sanitary support [1].

In this regard, the study was aimed to develop the methodological basis for the medical and sanitary support of the nuclear industry enterprise personnel radiation safety during the nuclear legacy elimination on the example of SCP (CATU Seversk). For that the following tasks were accomplished: selection of the area for the development of methodological support of activities on ensuring radiation safety during elimination of nuclear legacy was substantiated; death rates caused by cancers of most common localizations were defined; the risk of dying from cancers of most common localization in employees engaged in decommissioning the nuclear industry enterprise (nuclear legacy) was assessed; directions for improvement of the medical support of employees engaged in the nuclear legacy elimination were determined.

During the study we managed to justify the use of CATU Seversk as a platform for the development of methodological support of activities on the scheduled nuclear legacy decommissioning. The analysis of death rates caused by malignant neoplasms of bronchi, trachea, lung, stomach, colon, lymphoid, hematopoietic and related tissues, breast and prostate glands, and skin among male and female SCC employees in 1970–2019 made it possible to reveal the increase in the studied indicators, except for the malignant neoplasms of the stomach in women. It is clear that the increase in cancer mortality observed in the studied population is mainly due to the population ageing. This is clearly illustrated

Table 6. Death rates caused by cancer among adult female population of CATU Seversk in 1970–2019 (per 100,000 population; group average)

Cancer localization (ICD-10 code)	Range within the studied period, years									
	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Stomach (C16)	31.3	15.9	24.7	27.2	18.9	21.7	19.6	38.8	15.9	25.4
Colon (C18)	4.5	4.3	7.7	7.4	16.3	6.8	23.5	18	19.5	22.5
Trachea (C33)	0	0	0	0	0	0	0	0	0	0
Bronchi and lung (C34)	6.8	2.3	9.7	7.6	12.4	3.5	15.5	9.8	11.4	24.5
Skin (C43–44)	0.3	2.2	0.4	0.6	1.9	3.6	13.8	8.4	3.4	4.5
Breast (C50))	4.8	12.9	15	18.9	19.1	25.9	30.2	36.5	38.4	30.6
Lymphoid, hematopoietic and related tissues (C81–96)	4.9	12.9	9.5	5.3	17.4	22.3	19.9	8.1	9.1	15.9

Table 7. SRR of dying from cancer in male nuclear industry enterprise employees based on TED (95% confidence interval)

Cancer localization	TED, mSv							
	0–20	> 20–50	> 50–100	> 100–150	> 150–200	> 200–300	> 300–500	> 500–1 000
Stomach and colon	0.68 (–0.11–5.18)	0.70 (–0.10–0.94)	1.06 (0.04–1.34)	0.49 (–0.16–0.69)	0.73 (–0.09–0.97)	0.74 (–0.09–0.98)	0.98 (0.01–1.25)	1.25 (0.14–1.56)
Trachea, bronchi, and lung	0.52 (–0.15–4.90)	0.48 (–0.16–0.70)	0.66 (–0.11–0.92)	0.54 (–0.15–0.77)	1.24 (0.13–1.58)	1.09 (0.06–1.41)	0.49 (–0.16–0.72)	2.29 (0.73–2.73)
Skin	–	1.59 (0.15–4.99)	2.08 (0.32–5.72)	–	–	–	2.21 (0.37–5.91)	–
Prostate gland	0.69 (–0.06–5.20)	0.24 (–0.04–1.13)	1.26 (0.10–2.61)	0.57 (–0.08–1.65)	0.85 (–0.03–2.05)	3.08 (1.03–4.93)	3.96 (2.18–6.61)	3.16 (1.60–5.60)
Lymphoid, hematopoietic and related tissues	0.77 (–0.06–5.34)	0.73 (–0.07–1.45)	0.96 (0.00–1.75)	0.58 (–0.10–1.25)	0.86 (–0.06–1.62)	1.25 (0.11–2.12)	1.36 (0.16–2.25)	0.53 (–0.11–1.18)

Table 8. SRR of dying from cancer in female nuclear industry enterprise employees based on TED (95% confidence interval)

Cancer localization	TED, mSv					
	0–20	> 20–50	> 50–100	> 100–150	> 150–200	> 200–300
Stomach and colon	0.6 (0.45–5.13)	1.07 (0.82–5.86)	0.48 (0.32–4.83)	1.78 (1.42–6.97)	0.56 (0.38–4.97)	1.07 (0.82–5.86)
Trachea, bronchi, and lung	1.93 (1.20–7.25)	0.49 (0.16–4.83)	0.80 (0.36–5.39)	1.75 (1.05–6.96)	–	–
Skin	–	1.65 (0.55–6.80)	–	5.94 (3.59–13.06)	–	–
Breast	1.66 (1.18–6.81)	0.66 (0.38–5.15)	0.36 (0.16–4.61)	1.58 (1.12–6.69)	1.27 (0.86–6.18)	–
Lymphoid, hematopoietic and related tissues	0.18 (0.02–4.27)	0.83 (0.41–5.43)	0.69 (0.30–5.18)	2.97 (2.11–8.83)	–	–

by the above population dynamics of the major age groups. The analysis of the SCP employees' SRR of dying from cancer of key localizations has made it possible to reveal the significant increase (compared to non-exposed employees) in the studied indicators for prostate cancer in males and malignant neoplasms of trachea, bronchi, lung, stomach, colon, skin, breast, lymphoid, hematopoietic and related tissues in females. The findings are generally consistent with the results obtained by other authors [2–4]. However, we believe that our findings cannot form the basis for definitive conclusions about the impact of ionizing radiation on cancer in employees of the nuclear industry enterprises. That is why further research is required involving larger samples of employees.

In our study we defined the main phases of improving the medical support of employees during elimination of nuclear legacy (identification of the set of risk factors, formulation of proposals to manage the major risk factors, development of the strategy for medical support of employees engaged in the activities on the nuclear legacy decommissioning).

CONCLUSIONS

During the study, information about the SRR of dying from the most common cancer types and the dynamic changes in cancer mortality in the nuclear industry enterprise employees was obtained. This data makes it possible to adjust medical support of the nuclear industry enterprise employees in order to extend their working longevity, as well as to reduce the adverse rediation-induced health effects in people engaged in the nuclear legacy elimination. The findings will provide the basis for the information and methodological documents to be used in the practice of scientific and medical institutions that provide medical support of the activities at the nuclear facilities and are responsible for health monitoring in employees of these facilities and the population of the adjacent areas.

References

1. Ilyin LA, redaktor. Texnogennoe obluchenie i bezopasnost' cheloveka. M.: IzdAT, 2006; 304 s. Russian.
2. Shilnikova NS, Preston DL, Ron E, Gilbert ES, Vassilenko EK, Romanov SA, et al. Cancer mortality risk among workers at the Mayak nuclear complex. Radiat Res. 2003; 159 (6): 787–98. DOI: 10.1667/0033-7587(2003)159[0787:cmrawa]2.0.co;2.
3. Zablotska LB, Ashmore JP, Howe GR. Analysis of mortality among Canadian nuclear power industry workers after chronic low-dose exposure to ionizing radiation. Radiat Res. 2004; 161 (6): 633–41. DOI: 10.1667/rr3170.
4. Gilbert ES, Koshurnikova NA, Sokolnikov ME, Shilnikova NS, Preston DL, Ron E, et al. Lung cancer in Mayak workers. Radiat Res. 2004; 162 (5): 505–16. DOI: 10.1667/rr3259.
5. Auvinen A, Pukkala E, Hyvönen H, Hakama M, Rytömaa T. Cancer incidence among Finnish nuclear reactor workers. J Occup Environ Med. 2002; 44 (7): 634–8. DOI: 10.1097/00043764-200207000-00008.
6. Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, et al. Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. BMJ. 2005; 331 (7508): 77. DOI: 10.1136/bmj.38499.599861.E0.
7. Jeong M, Jin YW, Yang KH, Ahn Y-O, Chaet C-Y. Radiation exposure and cancer incidence in a cohort of nuclear power industry workers in the Republic of Korea, 1992–2005. Radiat Environ Biophys. 2010; 49 (1): 47–55. DOI: 10.1007/s00411-009-0247-7.

Литература

1. Ильин Л. А., редактор. Техногенное облучение и безопасность человека. М.: ИздАТ, 2006; 304 с.
2. Shilnikova NS, Preston DL, Ron E, Gilbert ES, Vassilenko EK, Romanov SA, et al. Cancer mortality risk among workers at the Mayak nuclear complex. Radiat Res. 2003; 159 (6): 787–98. DOI: 10.1667/0033-7587(2003)159[0787:cmrawa]2.0.co;2.
3. Zablotska LB, Ashmore JP, Howe GR. Analysis of mortality among Canadian nuclear power industry workers after chronic low-dose exposure to ionizing radiation. Radiat Res. 2004; 161 (6): 633–41. DOI: 10.1667/rr3170.
4. Gilbert ES, Koshurnikova NA, Sokolnikov ME, Shilnikova NS, Preston DL, Ron E, et al. Lung cancer in Mayak workers. Radiat Res. 2004; 162 (5): 505–16. DOI: 10.1667/rr3259.
5. Auvinen A, Pukkala E, Hyvönen H, Hakama M, Rytömaa T. Cancer incidence among Finnish nuclear reactor workers. J Occup Environ Med. 2002; 44 (7): 634–8. DOI: 10.1097/00043764-200207000-00008.
6. Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, et al. Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. BMJ. 2005; 331 (7508): 77. DOI: 10.1136/bmj.38499.599861.E0.
7. Jeong M, Jin YW, Yang KH, Ahn Y-O, Chaet C-Y. Radiation exposure and cancer incidence in a cohort of nuclear power industry workers in the Republic of Korea, 1992–2005. Radiat Environ Biophys. 2010; 49 (1): 47–55. DOI: 10.1007/s00411-009-0247-7.