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THE ANALYSIS OF 2002-2024 DEATH CAUSES IN INDIVIDUALS EXPOSED TO PROLONGED IONIZING RADIATION

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Abstract

The study is aimed to analyze the death causes of the population exposed to prolonged ionized radiation due to living near the Semipalatinsk nuclear test site.

Materials and methods of the study. The initial information for creating the cohort was the data of the study implemented in 1998-2002 with 3539 randomly selected individuals affected by the Semipalatinsk Nuclear Test Site. For each cohort member having the vital status “Dead” the date and cause of the death are verified.

Results. The studied cohort included 50.6% men and 49.4% women. The main causes of death of residents of villages exposed to prolonged exposure to ionizing radiation were diseases of the circulatory system - 54.7%; neoplasms - 20.7%; respiratory diseases - 7.1%. Life expectancy was higher in women than in men, however, did not differ depending on nationality, and differed statistically significantly depending on the area of residence. The frequency of circulatory system diseases as a cause of death was higher in residents of areas with extreme, maximum and increased radiation risk compared to residents of areas of minimum radiation risk.

Our research demonstrates the need of further study of the correlation of mortality and diseases of circulation system and cancer and prolonged exposure to radiation as a result of living near Semipalatinsk Nuclear Test Site.

Key words: Semipalatinsk nuclear test site, areas of radiation risk, mortality, death causes.

Резюме

АНАЛИЗ ПРИЧИН СМЕРТИ ЗА 2002-2024 гг. У ЛИЦ, ПОДВЕРГШИХСЯ ПРОЛОНГИРОВАННОМУ ВОЗДЕЙСТВИЮ ИОНИЗИРУЮЩЕЙ РАДИАЦИИ

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Цель. Настоящее исследование направлено на анализ причин смерти населения, подвергшегося пролонгированному воздействию ионизирующего излучения вследствие проживания вблизи Семипалатинского испытательного ядерного полигона.

Материалы и методы исследования. Исходной информацией для формирования когорты послужили данные исследования, проведенного в 1998-2002 гг., где приняло участие 3539 лиц, выбранных методом «случайного

отбора», из числа случайно отобранных лиц, пострадавших в результате деятельности СИЯП. Для каждого члена когорты, имеющего жизненный статус «Умер», верифицирована дата и причина смерти.

Результаты. Исследуемая когорта на 50,6% состоит из мужчин и 49,4% из женщин. Основными причинами смерти жителей сел, подвергшихся пролонгированному воздействию ионизирующего излучения можно отнести болезни системы кровообращения – 54,7%; новообразования – 20,7%; болезни органов дыхания – 7,1%.; Исследуемая когорта на 50,6% состоит из мужчин и 49,4% из женщин. Продолжительность жизни была выше у женщин, чем у мужчин, не отличалась в зависимости от национальной принадлежности, и статистически значимо различалась у лиц, в зависимости от зоны проживания. Частота болезней системы кровообращения, как причина смерти, значительно выше у лиц, проживавших в районах с чрезвычайным, максимальным и повышенным радиационным риском ($p = 0,02$) в сравнении с лицами, проживавшими в зоне минимального радиационного риска.

Вывод. Наше исследование показывает необходимость дальнейшего изучения связи между смертностью от болезней системы кровообращения и злокачественных новообразований с длительным воздействием радиации в результате проживания вблизи Семипалатинского ядерного полигона.

Ключевые слова: Семипалатинский испытательный ядерный полигон, зоны радиационного риска, смертность, причины смерти.

Түйіндеме

ИОНДАУШЫ СӘУЛЕЛЕРДІҢ ҰЗАҚ ӘСЕРІНЕН ҰШЫРАҒАН АДАМДАРДЫҢ, 2002-2024 жж ӨЛУ СЕБЕПТЕРІҢ ТАЛДАУЫ

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Бұл зерттеу халықтың өлімінің себептерін талдауға бағытталған, Семей ядролық сынақ полигонының жанында тұрып иондаушы сәулеленудің ұзақ әсер етуіне ұшырағандар.

Зерттеу материалдары мен әдістері. Когортты қалыптастыру үшін бастапқы ақпарат 1998-2002 жылдары жүргізілген зерттеу деректері болды, онда "кездейсоқ іріктеу" әдісімен таңдалған 3539 адам СИЯП қызметінің нәтижесінде зардап шеккен кездейсоқ таңдалған адамдар арасынан қатысты. "Қайтыс болған" өмірлік мәртебесі бар когорттың әрбір мүшесі үшін өлімнің күні мен себебі тексеріледі.

Нәтижелер. Зерттелетін когорт 50,6% ер адамдар мен 49,4% әйел адамдар болды. Иондаушы сәулеленудің ұзақ әсеріне ұшыраған ауыл тұрғындарының өлімінің негізгі себептеріне қан айналымы жүйесінің аурулары – 54,7%; ісіктер – 20,7%; тыныс алу органдарының аурулары – 7,1%.; Зерттелетін когорт 50,6% еркектерден және 49,4% әйелдерден тұрды. Әйелдердің өмір сүру ұзақтығы жоғары болды, ұлттық тиесілілігі ерекшеленбеді және тұрғылықты жеріне байланысты адамдар арасында статистикалық тұрғыдан айтарлықтай өзгерді. Өлімнің себебі ретінде қан айналымы жүйесі ауруларының жиілігі ең төменгі радиациялық тәуекел аймағында тұратын адамдармен салыстырғанда Төтенше, ең жоғары және жоғары радиациялық тәуекелі бар аудандарда ($p = 0,02$) тұратын халықта айтарлықтай жоғары болды.

Қорытынды. Біздің зерттеуіміз Семей ядролық полигонының маңында тұру нәтижесінде радиацияның ұзақ әсер етуімен қан айналымы жүйесі ауруларынан болатын өлім-жітім мен қатерлі ісіктер арасындағы байланысты одан әрі зерделеу қажеттігін көрсетеді.

Т сөздер: Семей ядролық сынақ полигоны, радиациялық қауіп аймақтар, өлім, өлім себептері.

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Introduction

The radiation legacy of the Semipalatinsk Nuclear Test Site (SNTS) is not only the residual radioactive contamination of its test sites and environmental objects, but also the consequences of exposure of the population living in the areas of radioactive fallout. The territory of the SNTS partially takes the area of Abay, East Kazakhstan, Pavlodar and Karaganda regions of the Republic of Kazakhstan. The total area is 18500 square kilometers, the perimeter is about 600 km. From 1949 to 1963 (the main dose-forming period), 118 atmospheric nuclear tests were conducted at the SNTS: 25 - nuclear tests in the form of ground nuclear explosions, 5 - prepared, but unperformed ground nuclear explosions; 88 - air nuclear explosions.

The amounts and manifestations of the remote effects of ionizing radiation depend both on the dose and nature of irradiation and on the sensitivity of tissues, organs and organ systems to the effects of ionizing radiation. It is known that tissues, organs and organ systems that are more sensitive to radiation realize the effects of irradiation earlier. However, recovery of disordered functions cannot be determined by the same correlation, especially in cases when irradiation is repeated, when acute irradiation is combined with chronic irradiation [1-2,4].

A number of research studies carried out at the Research Institute of Radiation Medicine and Ecology, as well as scientific publications by domestic and foreign scientists based on the results of scientific research in the field of radiation medicine [6,9,7,5,8] are devoted to the issues of medical consequences for the population exposed to excessive ionizing radiation.

The analysis of the nature of changes in mortality rates allowed to record their significant excess among the main groups compared to the control groups, both in terms of total mortality rates and individual classes of diseases as causes of death. The average annual rate of total mortality among the exposed population at a dose of 20 centi-Sievert and more was significantly higher than in the control group and ranged from 1915.6-1938.4 cases per 100,000 population, while in the control group it was 1109.2-1902.7 cases. The average annual relative risk was 1.74. The highest radiogenic risks are registered for cancer (1.87), diseases of the circulatory system (1.86) and diseases of the respiratory system (1.93). Lung and bronchial cancer (27.6%), breast cancer in women (20.5%), cancer of the gastrointestinal tract (15.2%), cancer of the eye, brain (8.2%), lymphoid and hematopoietic tissues (9.5%) prevailed in the structure of cancer mortality of individuals exposed to radiation. The share and level of mortality rates from cancer (except for cancer of gastrointestinal tract organs) were significantly higher by 1.7-2.3 times among the exposed population compared to the control group. The obtained results indicated a significant excess of mortality rates from circulatory system diseases in the main group and the comparison group, both for the total index and for individual classes of the most frequently registered diseases as causes of death [8-9,11]. These data indicate that even 50 years after the beginning of irradiation in persons with the established level of effective equivalent dose of 20 centi-Sievert and higher there is no decrease in radiation effects of ionizing radiation due to natural temporary dose reduction. The presence of effects in the

form of non-cancer diseases in groups of offspring born from irradiated parents has also been shown, which, in turn, requires appropriate evidence (indication of pathogenetic mechanisms) of the possibility of inheritance of stochastic effects of ionizing radiation of parents by their offspring [12,13].

Thus, a limited literature sources on main causes of death of population overexposed to ionized radiation is available. Therefore, the assessment of causes of death among individuals exposed to prolonged radiation as a result of living near the Semipalatinsk nuclear test site is of interest to the scientific community and practical health care.

Purpose of the study. Assessment of the death causes in residents of villages exposed to prolonged ionized radiation due to living near Semipalatinsk Nuclear Test Site.

Materials and methods of the study

The initial information for the creating of the study cohort was based on the data of the project implemented in 1998-2002 to study the state of the thyroid gland in residents living in the territories exposed to prolonged exposure to ionizing radiation as a result of living near Semipalatinsk Nuclear Test Site [14]. A total of 3539 people were included in the study. In 1998, 3009 people living in the territories of Abay (Karaul and Sarzhal villages), Beskaragay (Beskaragai, Dolon and Kanonerka villages), Borodulikha (Korosteli and Novopokrovka villages) districts and on the territory of Semey municipal administration (Kainar village) were examined. From 1999 to 2002, 530 people living in the territories of Abay (Sarzhal village), Beskaragay (Dolon village), Kokpekty (Kokpekty village) districts and on the territory of Semey municipal administration (Kainar and Socialistik villages, Semey city) were examined. Division by areas of radiation risk was performed according to the law of the Republic of Kazakhstan dated December 18, 1992 N 1787-XII "On social protection of citizens affected by nuclear tests at the Semipalatinsk nuclear test site".

At the first stage of creating the study cohort, cohort members were randomly selected from the State Scientific Automated Medical Register (SSAMR) of people affected by Semipalatinsk nuclear test site.

The registry contains information on each study participant including passport data, radiation route, vital status, education, job, availability and numbers of official documents, as well as medical information and, in case of death, the cause of death. Each participant included in the registry is assigned an individual number allowing access to all information available.

The selection of the cohort for studying the causes of death of residents of villages exposed to prolonged ionizing radiation as a result of living near Semipalatinsk Nuclear Test Site was based on the data for 1998-2002. General information was used as input parameters: surname (in rare cases first name); date of birth; sex; place where the study was conducted; the most radioactively contaminated place of residence (in all cases coincides with the place of the study).

When the identification of persons who underwent the study in 1998-2002 was carried out using the SSAMR database, 299 duplicate records (4 for 1998 and 295 for 1999-2002) were found out of 3539 persons. Thus, at the cohort

creation stage of this study, the final number of individuals totaled 3,240, of which those with a vital status of “Dead” totaled 1,945. For each member of the cohort with a “Dead” vital status, the date and cause of death was verified.

For confidentiality purposes, each cohort member is assigned a unique identification number that corresponds to the registration card number of a person exposed to radiation as a result of Semipalatinsk Nuclear Test Site activities in the SSAMR database.

Informing the study participants on the aims and tasks of the questionnaire and data collection, as well as their rights during study participation were signed by each participant of the project “Study Participant Information Sheet” and “Informed Consent on Study Participation” during individual survey of cohort members (1998-2002).

Statistical analysis was implemented using SPSS version 20 (IBM Corp.) and SNPStat version 2.2.1. All variables were tested for normality of distribution by the Kolmogorov-Smirnov statistical criterion. The nonparametric Kraskell-Wallace H-criterion was used for more than two groups.

Results

The total number of study cohort in the period 1998-2002 amounted to 3240 people. The largest number of study participants lived in the territory of the area of maximum radiation risk - 2390, which is 67.6% of the total number of those studied (Beskaragay, Kanonerka, Karaul, Novopokrovka and Socialistik villages). In the territory of extreme radiation risk 595 people (16.8% of the total number of surveys) were sampled (Dolon village and Sarzhal village), in the territory of increased radiation risk - 471 (13.3%) (Korosteli and Semey villages), and in the territory of minimal radiation risk - 83 people (2.3%) (Kokpekty village).

As of April 2024, 1099 members of the cohort were alive, 1945 people died, 192 people moved out of the study area, and 4 people have unknown vital status.

The places with residents having the vital status “Dead” are presented in Table 1.

Table 1.

Places of the cohort with the vital status «Dead».

№	District / village	Absolute number, (n=1945)	%
1	<i>Abay district</i>		
1.1	Karaul	352	18,1
1.2	Sarzhal	130	6,68
2	<i>Beskaragay district</i>		
2.1	Beskaragay	125	6,43
2.2	Dolon	113	5,81
2.3	Kanonerka	238	12,23
3	<i>Borodylikha district</i>		
3.1	Korosteli	293	15,06
3.2	Novopokrovka	379	19,49
4	<i>Kokpekty district</i>		
4.1	Kokpekty	19	0,98
5	<i>Semey municipal administration</i>		
5.1	Kaynar	277	14,24
5.2	Semey	13	0,67
5.3	Socialistic	6	0,31

The distribution of members of the study cohort with the vital status “Dead” by gender and nationality was analyzed (Fig. 1). The study cohort consists of 50.6% men and 49.4% women. The median age at the time of death in the entire study cohort was Me (Q1-Q3) = 71 (64-76), with a minimum of 22 years and a maximum of 93 years, among men Me = 69 years and women Me = 72 years. The mean age at death in the study cohort did not differ significantly by ethnicity (p = 0.1).

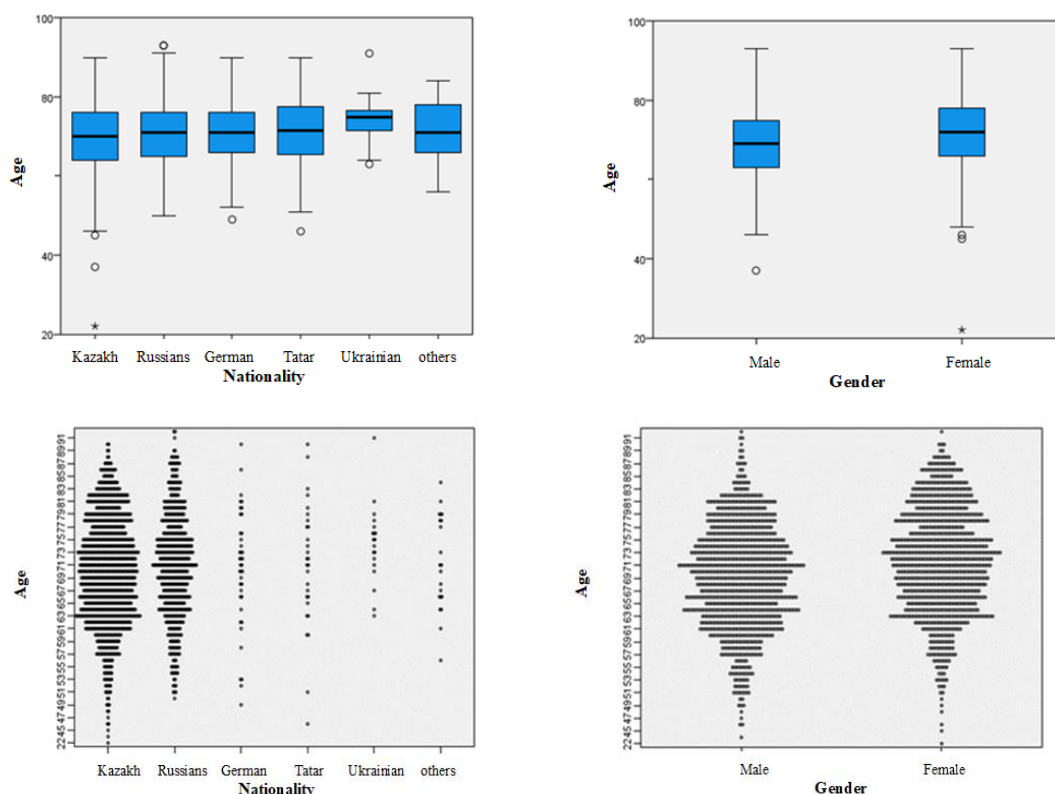


Figure 1. Demographic indicators of the cohort with the vital status «Dead».

Two main ethnic groups with different lifestyles and diets can be distinguished in the study cohort: the first includes Kazakhs and Tatars (57.7%), the second includes Russians, Ukrainians, Germans and other nationalities (42.3%).

Death causes were grouped according to the international classification of diseases ICD-10. The main death causes of the villages residents exposed to prolonged ionizing radiation are diseases of circulatory system – 54.7%, neoplasms – 20.7%, respiratory system diseases – 7.1% (Fig.2).

Symptoms, signs and abnormalities revealed by clinical and laboratory tests, not classified under other headings, accounted for only 5.7% of all causes of death, diseases of the nervous system - 2.8%; diseases of the digestive organs - 2.6%; injuries - 1.9%; other causes - 4.6% (Fig. 2).

Life expectancy statistically significantly differed depending on the area of residence ($p = 0.04$), however, it should be noted that the number of residents with the vital status “Dead” in the area of extreme radiation risk is 12.5%, maximum - 70.7%, increased - 33% and minimum - 1%.

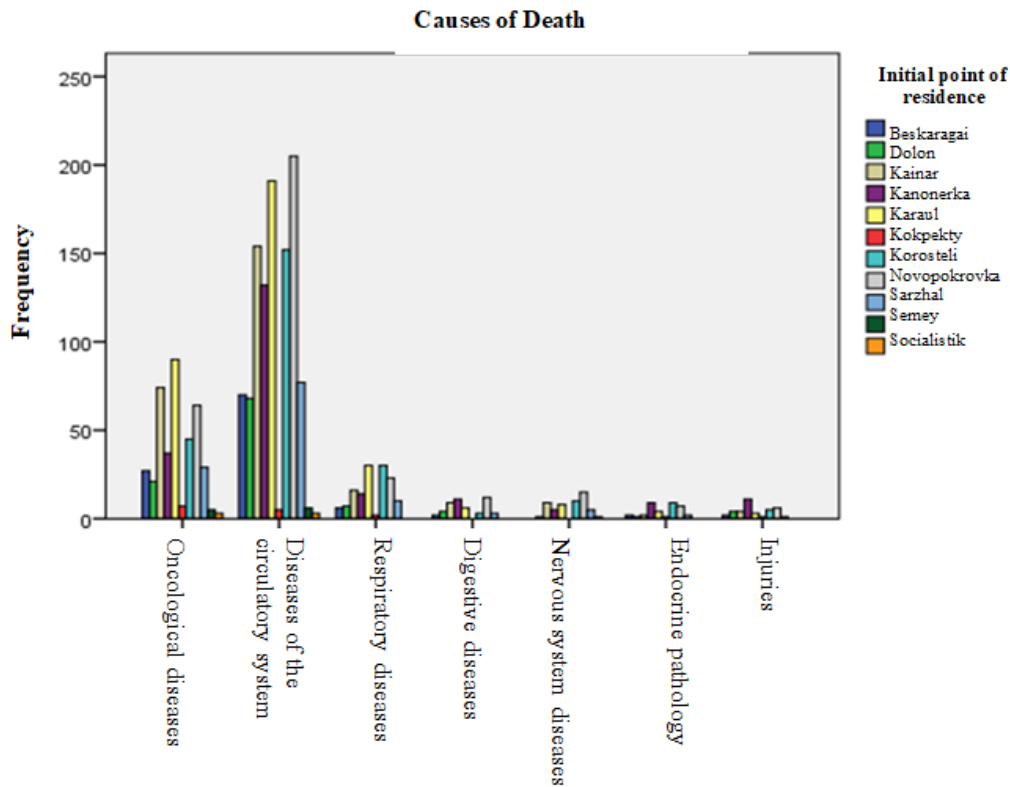


Figure 2. Main causes of death in residents of study areas.

Circulatory system diseases as a death cause were more common in residents of extreme, maximum and

increased radiation risk areas in comparison to residents living in areas of minimum radiation risk (table 2).

Table 2.

Distribution of death causes according to radiation risk areas.

Death cause	Area of extreme radiation risk, %	Area of maximum radiation risk, %	Area of increased radiation risk, %	Area of minimum radiation risk, %	Total, %
Circulatory system diseases	62.2	59.6	59.4	31.3	59.7
Neoplasms	21.5	23.3	18.8	43.7	22.6
Respiratory diseases	7.4	7.0	11.3	12.5	7.8
Diseases of digestive system	3.0	3.2	1.1	0	2.8
Diseases of the nervous system	2.5	2.8	4.1	0	3.0
Endocrine disorder	1.3	2.0	3.4	6.2	2.1
Traumas	2.2	2.0	1.9	6.2	2.1
Total, %	100.0	100.0	100.0	100.0	100.0

Neoplasms, respiratory diseases and traumas as causes of death were more common in residents of areas of minimum radiation risk (Kokpekty village) in

contrast to residents of extreme (Dolon and Sarzhal villages), maximum (Beskaragay, Kanonerka, Karaul, Novopokrovka and Socialistik villages) and increased

(Korosteli village and Semey municipal administration) radiation risk (Table 2).

Discussion

According to the official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan the main causes of death of residents of the Republic of Kazakhstan in 2022 are diseases of the circulatory system - 22.7%, neoplasms - 10.4%, diseases of respiratory system - 9.8%, accidents, poisonings and injuries - 8.4% and diseases of digestive organs - 8.0% (<https://stat.gov.kz/en/>). The main causes of death globally include cardiovascular (ischemic heart disease, stroke) and respiratory diseases (chronic obstructive pulmonary disease, lower respiratory tract infections) [3].

According to the results of the study, in the study cohort exposed to radiation as a result of Semipalatinsk Nuclear Test Site tests, diseases of the circulatory system - 59.7%, neoplasms - 22.6%, respiratory diseases - 7.7%, digestive diseases - 2.1%, poisoning and traumas - 2.1% - also take the first place. The frequency of such causes of death as diseases of the circulatory system and neoplasms was higher among residents of villages exposed to prolonged exposure to ionizing radiation compared to the national average. Conversely, the frequency of such causes of death as diseases of respiratory organs, digestion, poisoning and traumas in residents of the studied villages was lower than the national average.

Ionizing radiation is known to increase the risk of cancer, but there are also studies in the literature that show an increased risk of cardiovascular disease and stroke in patients who have undergone high-dose radiation therapy for Hodgkin's disease, breast cancer, and peptic ulcer disease [16]. In a study conducted in a cohort of atomic bomb survivors, the Radiation Effects Research Foundation found a statistically significant increase in the risk of cardiovascular disease, stroke, digestive and respiratory diseases [17]. The association between mortality from circulatory system diseases and low and moderate doses of ionizing radiation is also confirmed by a number of authors [17,18].

Conclusion

To summarize, it can be said that the main causes of death of residents of villages that were exposed to prolonged ionizing radiation due to living near the Semipalatinsk nuclear test site are diseases of the circulatory system, cancer and respiratory diseases. These results correspond to the main causes of mortality throughout Kazakhstan, but exceed the average values for the country as a whole. Thus, our paper still shows the importance of further study of the relationship between prolonged exposure to ionizing radiation as a result of living near the Semipalatinsk nuclear test site and the risk of mortality from cardiovascular diseases and cancer.

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scientific and pedagogical staff of NC JSC "Semey Medical University" for 2023-2025 (Agreement No. 4 dated January 20, 2023)

Literature:

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