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Original article

Assessment of the Risk of Somatic Diseases among the Population Living in the Zone of Influence of Uranium Mining Enterprises: Bidirectional Cohort Study

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Abstract

The purpose of the study was to assess the risk of the impact of technogenic factors of uranium mining enterprises on the health of the population living near the Syrdarya uranium ore province.

Materials and methods: the results of a bidirectional cohort study among residents living in the zone of influence of uranium mining enterprises – Bidaikol village of Kyzylorda region are presented.

Results: the prevalence of acute and chronic diseases among residents of Bidaikol village was 1.3 times higher than in the control group. Pathology of the genitourinary system (27%), diseases of the circulatory system (14.4%), diseases of the respiratory system (11.9%) prevailed in the structure of morbidity of the adult population. Relative risks > 1 were identified for most classes of diseases: the highest for diseases of the blood (RR=2.6), skin (RR=2.3) and genitourinary system (RR=1.9). Renal pathology in the main group prevailed in the age group of 30-40 years, occurred mainly in women and had a direct dependence on the duration of residence in the territory of the uranium ore province.

Conclusions: a higher morbidity rate of residents of settlements located near the operating uranium deposits of the Syrdarya uranium ore province with the prevalence of tubulointerstitial diseases of the genitourinary system was revealed.

Keywords: uranium mining deposits, relative risk, morbidity, kidney pathology.

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Introduction

According to the World Nuclear Association (WNA), the Republic of Kazakhstan ranks first in the world in uranium ore mining and second after Australia in explored uranium reserves [1]. The growing pace of uranium mining in Kazakhstan is accompanied by an aggravation of a number of problems: the need for disposal of radioactive waste, the rehabilitation of radioactively contaminated territories, and the reduction of the negative impact of radiation-toxic factors on workers and the population of uranium mining regions. Currently, there are persistent negative trends in the health status of the population, due to the impact of adverse environmental factors [2,3]. The problem of environmentally determined pathology is especially relevant for the uranium regions of Kazakhstan. One of the largest uranium-ore provinces of the Republic is Syrdarya. At its deposits, as in most uranium mining enterprises (UDP) of the Republic, the method of in-situ borehole leaching (ISL) is used. It is believed that the extraction of uranium by the ISL method is relatively safe and does not violate the existing natural conditions of the subsoil and surface. Nevertheless, underground leaching may contaminate the aquifer and the earth's surface with technogenic radionuclides harmful to human health [4]. At the same time, the assessment of the effects of human-induced exposure on the population in the range of low doses remains the subject of numerous discussions and the priority task of many studies [5]. The closest to the uranium deposit "Northern Karamuryn" of the Syrdarya uranium ore province is the village of Bidaykol, Kyzylorda region. According to 2022 data, more than 4 thousand people live there, but so far no studies have been conducted to assess the health status of the population living in the zone of influence of uranium mining enterprises. This work is relevant and subsequently provides for the development of rehabilitation measures aimed at reducing radiation risks for the population as a result of the activities of uranium mining enterprises.

The purpose of our study was to assess the risk of the impact of technogenic factors of uranium mining enterprises on the health status of the population living near the UDP of the Syrdarya uranium ore province.

Materials and methods

The study of the health status of the population living in the zone of influence of operating uranium mining enterprises was carried out within the framework of the project "Development of methods for leveling negative technogenic risk factors for the environment and health of the population of the Syrdarya uranium ore province" (No. 158 / 36-21-23 from 04/27/2021, IRN AP09261243). This research work is a comprehensive radiological and epidemiological study aimed at solving a number of problems in the management of radioecological risks, and also provides for the development of a system of rehabilitation measures aimed at mitigating the effects of radioactive contamination of the environment and reducing the radiation risks of the population as a result of the activities of uranium mining enterprises.

For epidemiological analysis, a bidirectional cohort research method was used: a cohort was formed in 2021 and is tracked partly in the past (retrospectively) and partly prospectively. The study cohort included as the main group the population of the village of Bidaykol, Shieli district, which is located 4 km from the uranium mining enterprise (n=3754), and as a control group, residents of the village of Sunakata, Zhanakorgan district, Kyzylorda region, located 15 km from the nearest uranium mining enterprise (n=1851). The main selection criterion for the study groups was a long period of residence in these territories - more than 15 years. The exclusion criterion was professional contact with sources of ionizing radiation - the fact of working at uranium mining enterprises. The distribution of the population by age and sex is presented in Table 1.

Table 1 - Characteristics of the population of the main and control groups

Characteristic/locality	Bidaykol village	Sunakata village
Number of people in study groups	3754	1851
Under 18 years old	1703 (45%)	749 (40%)
Over 18 years old	2051 (55%)	1102 (60%)
Adult population		
Average age	43±16	44±16
Female	1102 (54%)	524 (48%)
Male	949 (46%)	578 (52%)

When analyzing the results of the study, relative risks (RR) were calculated for all classes of diseases. For this purpose, the database of the Institute of Radiobiology and Radiation Protection was used - a radiation-epidemiological register, in which information about each person was entered on the basis of data from the medical records of an outpatient. Categorical variables were compared using a non-parametric $\chi 2$ test. The analysis was performed using IBM SPSS Statistics 20 software and Microsoft Excel.

Results

To compare the frequencies and the expected probability of developing somatic morbidity, groups were created according to the main nosologies of ICD-10 that are present in the population of the studied villages. When analyzing cases of diseases in the population from 18 years of age in the main group living near uranium enterprises, it was found that the prevalence of diseases for most classes of diseases according to ICD-10 exceeds that in the control group of people living farther from the enterprises of the uranium mining industry (Figure 1). At the same time, diseases of the genitourinary system remained in first place (27%) - 641.6 per 1000 people in the village of Bidaykol and exceeded this indicator in the control group by almost 2 times (343.9 per 1000 people, $\chi 2=255.6$, p=0 .00). In the second position among the adult population - diseases of the circulatory system (14.4%), in third place - diseases of the respiratory system (11.9%). In the control group, diseases of the genitourinary system were also in first place, followed by diseases of the circulatory and digestive systems. The exception was infectious diseases, which prevailed among the inhabitants of the control group - the village of Sunakata and diseases of the endocrine system, but the difference between the groups was statistically insignificant.

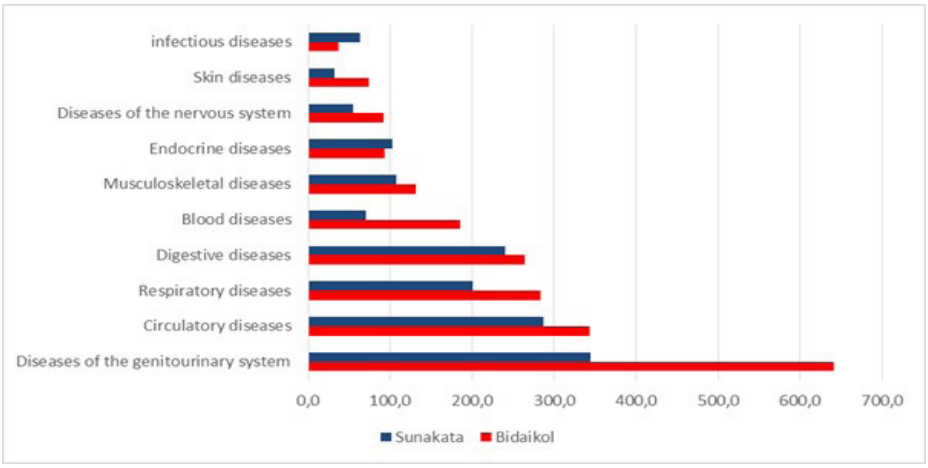

Figure 1 - Comparative characteristics of the prevalence of diseases in the population of the studied groups (per 1000 people)

To determine the risk of diseases in the main group in relation to the control group, the relative risks (RR) were calculated according to the ICD-10 classes. The highest RR was for blood diseases and amounted to 2.6 with CI 2.0-3.3. Among diseases of the blood system, anemia prevailed - 17.4 per 100 people. For skin diseases - RR=2.3, CI 1.6-3.5, diseases of the genitourinary system RR=1.9, CI 1.7-2.1. (Figure 2).

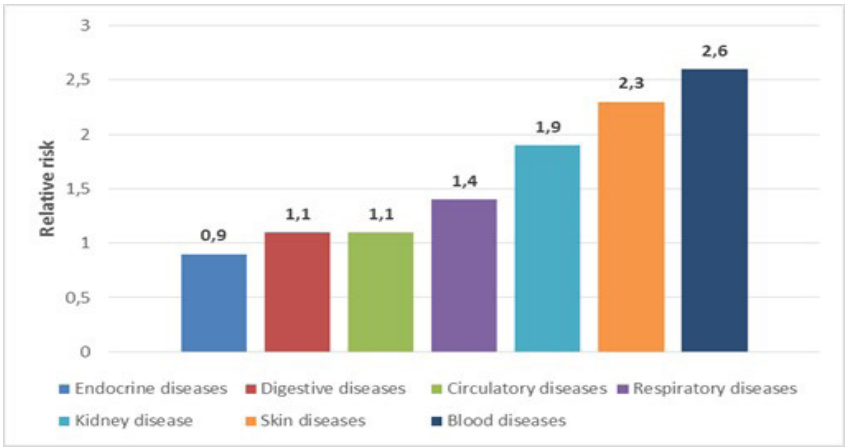

Figure 2 - Relative risks of somatic diseases in the population of Bidaikol village by ICD-10 classes

A comparative assessment of the prevalence of diseases in the study groups by age was carried out in order to identify age groups of "risk" (Table 2). No pronounced patterns were found when comparing the frequency of occurrence of diseases in the main and control groups for the prevailing classes of diseases, while in general, for all diseases included in the ICD-10, statistically significant differences were found in older age groups. In the context of individual classes of diseases, this trend was especially clearly observed for diseases of the circulatory system in the population of the Bidaikol village, where the prevalence of diseases per 1000 people increased from 87.4 at the age of 20-30 to 1130.4 in people over 70 years of age ($\chi 2= 316, 3$, p=0.00).

Table 2 - The prevalence of the prevailing classes of diseases by age categories of the population of the Bidaykol village

Name of disease classes according to ICD-10	Age groups (years)					
	20-30	30-40	40-50	50-60	60-70	Older than 70
Number of people	366	482	420	323	243	138
Diseases of the genitourinary system	737,7	757,3	690,5	526,3	559,7	637,7
Diseases of the circulatory system	87,4	112,0	264,3	473,7	786,0	1130,4
Respiratory diseases	396,2	288,4	231,0	241,5	259,3	355,1

In contrast, diseases of the genitourinary system were common in all age groups with a peak at the age of 30-40 years - 757.3 per 1000 people. Statistically significant differences were found for diseases of the genitourinary system by gender: among women, their prevalence was 2 times higher and amounted to 892.0 versus 427.8 per 1000 people. In both sexes, diseases belonging to the category of "chronic tubulointerstitial nephritis" prevailed. In general, the frequency of occurrence of diseases of the prevailing classes (genitourinary, cardiovascular and respiratory systems) by gender showed preponderance for the female sex both in the main and in the control group.

In addition to age and gender, an analysis was made of the incidence of kidney diseases in people, depending on the length of residence in the territory in the zone of influence of uranium mining enterprises.

Table 3 - Kidney diseases in the population of the main group, depending on the length of residence in the territory of the uranium ore province

	Length of residence in Bidaykol village		
	10-20	20-30	over 30
Number of people	91	376	1581
Prevalence of kidney disease per 1000 people	75,3	405,8*	366,7*
Note: *p <0.001			

The prevalence of kidney diseases grew with an increase in the period of residence in the territory of the uranium ore province. Thus, the results of the studies showed a high prevalence of diseases of the urinary system among the residents of the village of Bidaykol compared with the control group and the dependence of the incidence of kidney diseases on age, gender and length of residence in the study area.

Discussion

The problem of environmental pollution with natural and man-made transuranium radionuclides exists in many countries of the world. But it is especially characteristic of the countries of the former Soviet Union: Tajikistan, Kazakhstan, the Kyrgyz Republic, Uzbekistan [6]. Historically, in many post-Soviet countries, uranium industry enterprises and radioactive waste storage facilities were located near settlements. In addition, they were often located directly in the channels and floodplains of the basins of transboundary rivers flowing into the densely populated valleys of the entire region. As a consequence, the environment may be contaminated with radionuclides [7-9]. It is known that radionuclides can enter the human body by inhalation, oral route and through the skin. For people living in areas contaminated with radionuclides, the enteral route is of greater importance. The population may be chronically exposed to radionuclides through drinking water or food [10,11]. The supply of uranium to humans with food is also important. The main food chains are: plants → human; plants→animal→milk→human; plants → animal → meat → human; plants → bird → egg → human; water→hydrobionts→human [12,13].

Preliminary studies on the assessment of the radiation and sanitary-hygienic situation in the village of Bidaykol, located in the zone of influence of active uranium mining deposits, showed that in soil samples, the excess of the specific activity of radionuclides was up to 5 times for Ra 226-, up to 4 times for Th 232 compared to national averages. In water samples taken from the wells of the Bidaykol settlement, the total alpha activity was up to 3 times higher than the control values. The water from the wells is used by the local population for watering the garden and watering the livestock. In water samples from a well with a depth of 12 meters in the village of Bidaykol, the concentration of uranium was up to 2 times higher than the maximum permissible concentration [14]. That is, all the described scenarios of enteral intake of radionuclides can be realized in the region under study. In turn, the incorporation of transuranium radionuclides can cause both functional and organic changes in individual organs and systems of human organs [15,16].

Assessing the health status of residents living near active uranium deposits, one can see that the prevalence of somatic diseases and the structure of morbidity differs from residents living in regions free

of radionuclides. Thus, the prevalence of diseases of all classes of the population of the village of Bidaykol was 1.3 times higher than those of the control settlement - the village of Sunakata. This pattern was observed both among the entire population - adults and children, and among the population over 18 years of age. Since the main selection criterion for the study groups was the period of residence in the studied settlements for more than 15 years, a detailed epidemiological study was conducted in the adult population.

In the structure of morbidity, the first ranking places among the population of the main group were diseases of the genitourinary system, cardiovascular and respiratory diseases. The sum of the share of these three classes of diseases accounts for more than half (53.3%) of all cases of diseases. A slightly different picture was in the control group: diseases of the digestive system were in third place. Next, intensive indicators (frequencies) of morbidity among workers in the main and control groups were calculated. This made it possible to determine the statistical significance of differences among those living in the uranium mining province for most classes of diseases (Figure 1). It should be noted that there are very few such studies of the health of the population living in radioactively contaminated areas near uranium deposits or enterprises. Over the past 10 years, there has been an increase in the number of studies in the United States on the impact of uranium on the health of members of local American Indian tribes: more than 200,000 people live less than 10 km from a uranium-vanadium mine. The legacy of this mine is the continued presence of uranium in the environment, including in many surface and underground water sources. The population living near the mines has been found to have a high prevalence of chronic disease compared to the general US population. These studies are ongoing [17].

In our study Relative risks (RR>1), which may indicate that living conditions near the uranium industry are a risk factor for human health, were also identified for almost all classes of diseases (Figure 2).

The highest RRs were characteristic of diseases of the blood, skin, and genitourinary system. The study of the long-term consequences of the action of radionuclides on the blood system remains one of the topical areas in biology and medicine. It is known that radionuclides, to a greater extent, affect the hematopoietic system by reducing leukocytopoiesis [18]. In our study, the main share in the structure of morbidity was occupied by anemia - iron deficiency or unspecified, which in turn requires a more in-depth analysis of the contingent of individuals, causes and laboratory studies of the inhabitants of the village of Bidaykol. Dermatitis and eczema prevailed among the skin diseases among the population of the main group, which could also hypothetically be the result of water and soil pollution by heavy metals from uranium mining deposits.

Thus, the main diseases characteristic of the region under study are diseases of the genitourinary system. In our study, the subclass "tubulointerstitial kidney disease" prevailed in the population, accounting for 80% of all MPS diseases. There are enough studies in the literature that have proven the nephrotoxicity of uranium [19-21].For example, the American Indian Health Survey found the highest prevalence of diabetes among all racial and ethnic groups in the United States. Kidney disease, a complication of poorly controlled diabetes, was twice as common in Indians as in whites. The researchers suggest that synergistic nephrotoxic effects of uranium on the development of diabetic kidney disease among AIs living near uranium mines cannot be ruled out [17].

In the medical records of outpatients in the village of Bidaykol with kidney diseases, the final diagnoses are either chronic pyelonephritis or the name of the subclass is duplicated - tubulointerstitial kidney disease A high incidence of kidney disease was found in all age groups with a peak at the age of 30-40 years. Diseases of the urinary system among women were 2 times more common. It is known that pyelonephritis in its frequency exceeds all renal diseases combined and are among the most common diseases of the urinary system associated with infection. However, according to statistics, in young women, pyelonephritis occurs 5-7 times more often than in men. A progressive increase in the incidence of pyelonephritis among men occurs only in the elderly and senile age: by this period, the functional activity of the prostate gland decreases, the protection of the urinary tract decreases, the frequency of hypertrophic and tumor processes in the prostate increases, leading to impaired urodynamics, which, together with microbial invasion, leads to pyelonephritis [22].

However, in our study, the difference in the prevalence of tubulointerstitial diseases among young men and women is not so great, which requires an in-depth analysis of the category of kidney diseases and clarification of the reasons for the rather high incidence of men. In addition, it is necessary to find out whether the majority of kidney diseases in the population of the Bidaykol village are of an infectious nature or are they tubulointerstitial nephritis? Tubulointerstitial nephritis is a heterogeneous group of acute or chronic abacterial, non-destructive lesions of the renal tubules and interstitium with the spread of the inflammatory process to all structures of the renal tissue [23]. One of the nosological forms of tubulointerstitial kidney damage are tubulointerstitial and tubular lesions caused by drugs and heavy metals. These forms of renal pathology may be the result of living in the zone of influence of uranium mining deposits. Thus, it is known that uranium has a toxic effect on the kidneys both as a heavy metal and as an alpha-emitting radionuclide [24]. The mechanism of action of uranium and transuranium radionuclides on the renal tissue is the deposition of uranyl ion in the epithelium of the tubules, followed by their damage [25,26].

In addition, it was found that the incidence of kidney pathology increased with an increase in the period of residence in the territories of the uranium province. This may be an additional risk factor for the population of the studied settlements. Research in this direction will continue. Further study of the relationship between the action of factors of environmental distress and the development of diseases of the urinary system will make it possible to determine ways to prevent this pathology among the population living in the area of operation of uranium mining enterprises.

Conclusion

Thus, the results of the epidemiological study indicate a higher morbidity among residents of settlements located near the active uranium deposits of the Syrdarya uranium ore province. Residents of the Bidaykol village are characterized by diseases of the genitourinary system, circulatory and respiratory systems. Tubulointerstitial kidney diseases occupy a leading place among the pathology of the genitourinary system. In this work, it was shown that the influence of factors of radiation and chemical nature on the occurrence of kidney pathology in people living for a long time near a uranium mining enterprise is not excluded. The results of the scientific work done indicate the need for additional clinical, epidemiological and experimental studies in this direction. In the future, it is planned to study the concentration of heavy metals in water samples, determine the content of uranium in the urine of the population of the village of Bidaykol, as well as an in-depth study of medical data on kidney pathology among the population.

Conflict of interests. The authors declare no conflict of interest.

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Contribution of the authors. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Elena Saifulina, Duisebai Janabaev, Polat Kazymbet and Aigerim Shokabayeva. The first draft of the manuscript was written by Elena Saifulina and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. Conceptualization: Polat Kazymbet and Duisebai Janabaev; Methodology: Elena Saifulina, Yerlan Kashkinbayev; Formal analysis and investigation: Yerlan Kashkinbayev, Aigerim Shokabayeva; Writing - original draft preparation: Elena Saifulina, Yerlan Kashkinbayev; Writing - review and editing: Polat Kazymbet and Duisebai Janabaev; Funding acquisition: Polat Kazymbet.

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Түйіндеме

Зерттеудің мақсаты - уран өндіруші кәсіпорындардың техногендік факторларының Сырдария уран кені провинциясының маңында тұратын тұрғындардын денсаулық жағдайына әсер ету қаупін бағалау.

Материалдар мен әдістері. Қызылорда облысы Бидайкөл ауылының уран өндіруші кәсіпорындарының әсер ету аймағында тұратын тұрғындар арасында екі бағытты когорттық зерттеу нәтижелері ұсынылған.

Нәтижелері. Бидайкөл ауылының тұрғындары арасында жедел және созылмалы аурулардың таралуы бақылау тобына қарағанда 1,3 есе жоғары болды. Ересек тұрғындардың ауру құрылымында несеп-жыныс жүйесінің патологиясы (27%), қан айналымы жүйесінің аурулары (14,4%), тыныс алу жүйесінің аурулары (11,9%) басым болды. Салыстырмалы қауіптер >1 аурулардың көптеген кластары бойынша анықталды: қан (RR=2,6), тері (RR=2,3) несеп-жыныс жүйесі (RR=1,9) аурулары үшін ең жоғары.

Негізгі топтағы бүйрек патологиясы 30-40 жас тобында басым болды, негізінен әйелдерде кездеседі және уран провинциясының аумағында тұру ұзақтығына тікелей байланысты болды.

Қорытынды. Несеп-жыныс жүйесінің тубулоинтерстициальды ауруларының басым болуымен Сырдария уран-кені провинциясының жұмыс істеп тұрған уран кен орындарының жанында орналасқан елді мекендер тұрғындарының аурушаңдығы жоғары екені анықталды.

Түйін сөздер: уран өндіретін кен орындары, салыстырмалы тәуекел, сырқаттанушылық, бүйрек патологиясы.

Оценка риска соматических заболеваний среди населения, проживающего в зоне влияния уранодобывающих предприятий: Двунаправленное когортное исследование

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Резюме

Цель исследования состояла в оценке риска воздействия техногенных факторов уранодобывающих предприятий на состояние здоровья населения, проживающего вблизи Сырдарьинской урановорудной провинции.

Материалы и методы: представлены результаты двунаправленного когортного исследования среди жителей, проживающих в зоне влияния уранодобывающих предприятий – села Бидайколь Кызылординской области.

Результаты: среди жителей села Бидайколь распространенность острых и хронических заболеваний была в 1,3 раза выше, чем в группе контроля. В структуре заболеваемости взрослого населения преобладала патология мочеполовой системы (27%), болезни системы кровообращения (14,4%), болезни дыхательной системы (11,9%). Относительные риски >1 были выявлены по большинству классов болезней: наиболее высокие для болезней крови (RR=2,6), кожи (RR=2,3) мочеполовой системы (RR=1,9). Почечная патология в основной группе преобладала в возрастной группе 30-40 лет, встречалась преимущественно у женщин и имела прямую зависимость от продолжительности проживания на территории урановорудной провинции.

Выводы: была выявлена более высокая заболеваемости жителей населенных пунктов, расположенных вблизи действующих урановых месторождений Сырдарьинской урановорудной провинции с превалированием тубулоинтерстициальных заболеваний мочеполовой системы.

Ключевые слова: урадодобывающие месторождения, относительный риск, заболеваемость, патология почек.