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Impact of Uranium Mining on Radiation Levels in Kazakhstan: A Case Study of Two Major Provinces

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Abstract. This paper presents a comparative assessment of the radiation situation in populated areas located near the North Kazakhstan and Shu-Sarysu uranium provinces. Using gamma spectrometry, pedestrian dosimetry, and radon monitoring, the study assesses gamma radiation levels, radon equilibrium equivalent volume activity, and results of radiospectrometry analyses of soil and water. Additionally, the influence of local geological and hydrogeological conditions, as well as historical mining activities, was analyzed to identify potential factors contributing to spatial heterogeneity in radiation indicators. The results indicate that in the territories of populated areas located near the two uranium provinces, in general, they remain within the natural background, but there are anomalous zones with excess radon EEVA values, and in some populated areas of the North Kazakhstan region, exceeding the limit values. Elevated concentrations of naturally occurring radionuclides were detected in certain soil and groundwater samples, suggesting localized sources of radiological impact. A comparison with historical monitoring data allowed for the identification of temporal trends and assessment of the effectiveness of existing environmental protection measures. The results emphasize the importance of continuous and comprehensive, systematic radiation monitoring programs in the territories of both mothballed and operating uranium mines to reliably protect public health and the environment.
Key words: Uranium mining; radiation exposure; radon; radiological monitoring; uranium province

Introduction

The Republic of Kazakhstan is a unique uranium ore region, accounting for approximately 30% of the world's uranium reserves. Kazakhstan ranks first in the world in uranium ore production. The major uranium deposits within Kazakhstan are grouped into six uranium

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ore provinces: Shu-Sarysu, North Kazakhstan, Syrdarya, Ili, Caspian, and Balkhash provinces. The largest of these are the Shu-Sarysu province, which contains about 69.7%, and the North Kazakhstan province, which contains about 12.1% of Kazakhstan's total uranium reserves [1,2].

These provinces form the foundation of Kazakhstan's uranium industry, securing the country's leading position in global uranium production and export.

The intensive industrial development of the North Kazakhstan province began in the mid-1950s, almost simultaneously with its discovery and the commencement of large-scale geological exploration activities in Kazakhstan. The deposits of the North Kazakhstan uranium ore province were developed exclusively through mining (both underground and open-pit methods), which led to significant negative changes in the surrounding environment [3]. Currently, the territory of the North Kazakhstan and Akmolinsk regions hosts decommissioned uranium facilities and radioactive waste storage sites. It should be noted that the main work on the conservation and liquidation of uranium deposits in the North Kazakhstan region was completed as early as 2007 [4]. However, there are no monitoring activities for the radioecological condition of natural environment objects. As a result, the population living near these areas is increasingly exposed to radiation, potentially suffering chronic radiation-chemical effects from low doses of ionizing radiation, as well as other dangerous and harmful radioactive substances and industrial factors. This combination can significantly amplify the effects of low-level radiation exposure [5].

Uranium exploration and mining in the Shu-Sarysu province began to develop actively in the 1950s and 1960s. Initial geological exploration activities related to the search for uranium deposits began in the 1950s, when geologists in Kazakhstan started to investigate potential areas with uranium reserves, including the territory of the Shu-Sarysu region.

In the early 1970s, industrial uranium mining commenced based on the explored deposits. The Shu-Sarysu uranium province became a key region for uranium production in the country, and Kazakhstan as a whole began to take a leading position in the global market. As infrastructure and mining technologies developed, production volumes continued to grow. Subsequently, uranium mining in this region became not only a significant economic factor for the country but also an important element in the global energy system.

The Shu-Sarysu province accounts for 60.5% of Kazakhstan's total uranium reserves and resources. Currently, uranium is being mined through in-situ leaching at the Uvanas, Mynkuduk, Kanzhugan, Moinkum, Akdala, Budennovskoye, and Inkai deposits. However, information regarding the radiation situation in this region is limited. Researching to assess the radiation situation in the territory and nearby settlements is an important step in ensuring the safety of the population, protecting public health and the environment, as well as in taking timely measures in case of elevated radiation levels. Such studies allow for the identification of potential risks, the assessment of radiation impact on ecosystems, and the development of effective strategies to minimize possible consequences.

It is known that uranium's radiation effect on humans can lead to stochastic radiation effects, including oncological diseases, genetic disorders, and non-oncological somatic diseases [6,7]. According to the International Agency for Research on Cancer, cancer morbidity and mortality are important and objective criteria for assessing the impact of ionizing radiation [8,9]. It is known that prolonged exposure to uranium and its daughter products increases the contribution of the radiation component. Based on the level of exposure (chronic effects of low doses), the mechanism of action (radiation-chemical), and the biological role of uranium in the life processes of organisms, the analysis is based on the results of long-term consequences and territories with varying uranium content in the environment [10].

This work aims to assess the radiation situation in the territories of settlements located near two major uranium provinces of Kazakhstan.

Materials and Methods

The study provides an assessment of the radiation situation and analyzes the results of the author's own research conducted in the territories of settlements located near decommissioned uranium mines and radioactive waste storage sites in North Kazakhstan: the settlement of Aksu, the settlement of Shantobe in the Akmola region, the settlement of Saumalkol in the North Kazakhstan region, and the territories of settlements located near uranium deposits: the settlements of Taukent, Taikonur, Shu, Zhuantobe, and Tasty in the Turkestan region (Fig. 1).

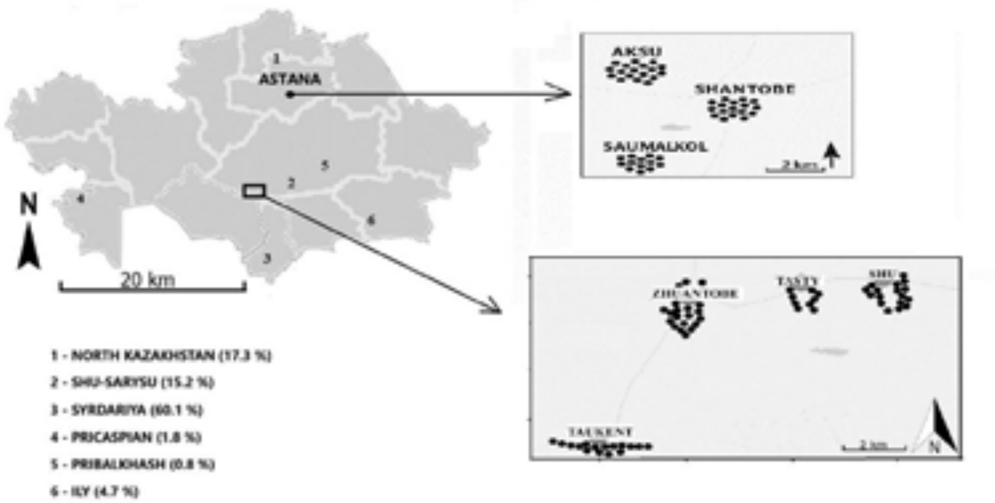

Figure 1. Locations of settlements and uranium provinces in Kazakhstan, showing the distribution of uranium reserves.

To assess the radiation situation, the following measurement methods were used:

Gamma scanning of the territory was conducted using a mobile automotive radiological laboratory "Gamma-Sensor" (SPC DOZA, Moscow, Russia) (Fig. 2). The spectrum acquisition time on the spectrometer was set to 15 s. With this acquisition time, the statistical deviation of the measured value of the equivalent dose rate (EDR) of gamma radiation at a given point from its root-mean-square value was no more than 0.005 μSv/h with a confidence level of 0.95. The vehicle speed during the survey was 6–10 km/h. The spectrometer was calibrated daily at the control point for energy, and the calibration for the dose rate and the values of the geodetic coordinates were checked simultaneously.

Figure 2. Mobile automotive radiological laboratory "Gamma-Sensor"

Pedestrian measurements of gamma background in background areas, in the territories of settlements, and outside the sanitary protection zones (SPZ) of decommissioned uranium deposits were performed using dosimeters DKS-AT-1123 (ATOMTEX Scientific Production Unitary Enterprise, Minsk, Republic of Belarus) and MKS-AT-1117M (ATOMTEX Scientific Production Unitary Enterprise, Minsk, Republic of Belarus) (Fig. 3). The dose rate measurements were conducted outdoors at a distance of 5 meters from the exterior walls, at a height of 1 meter. At each location, between 8 and 10 measurements were performed, and the average value was used for further analysis. The instrumental relative uncertainty of the DKS-AT-1123 dosimeters was 25%. All measurements were carried out in accordance with IAEA guidelines [11]. The relative uncertainty in the estimation of H*(10), considering the repeatability of in-situ measurements using the MKS-AT-1117M device, was approximately 20%. At each survey point, measurements of the ambient dose equivalent rate (EDR) were taken both at ground level and at a height of 1 meter.

Figure 3. Dosimeters DKS-AT-1123 and MKS-AT-1117M

The equivalent equilibrium volume activity of radon (EEVA) was measured using radon monitors “AlphaRad.” The registration of alpha particle pulses from daughter products contained on the filter was carried out using a semiconductor alpha particle detector with an area of 20 cm^2. The AlphaRad Plus radon monitor (Fig. 4) utilizes a semiconductor detector to measure the equilibrium-equivalent volumetric activity (EEVA). This device detects alpha particles emitted by radon and its short-lived progeny, specifically ^{218}Po and ^{214}Po, enabling the determination of radon concentration and subsequent calculation of EEVA. The EEVA represents the activity concentration of radon progeny in equilibrium with radon gas in air and is expressed in Bq/m^3. All measurements were conducted in accordance with ASTM D6327-10 [12].

Figure 4. AlphaRad Plus radon monitor

Indoor measurements were conducted during the summer season across all surveyed settlements to ensure consistency and enable subsequent comparison of the results. Laboratory analysis of environmental object samples for radionuclide content was conducted in the accredited testing laboratory of radiometry and radiochemistry at the Institute of Radiobiology and Radiation Protection.

Results

1.Radiation Situation in the Territories of Settlements Located Near Decommissioned Uranium Mines and Radioactive Waste Storage Sites in Northern Kazakhstan

The conducted studies revealed that there are localized contaminated areas in the surveyed settlements. Gamma scanning identified zones with EDR of gamma radiation levels, reaching up to 12 times higher than background values (0.15 μSv/h). The highest EDR levels were recorded near roadways and in the basements of residential buildings, which may be due to both the geological structure and the use of building materials with elevated radioactivity.

The concentration of equivalent equilibrium volume activity of radon (EEVA) in the studied residential and administrative buildings, in some cases, significantly exceeded the permissible limits. According to the republican regulatory documents maximum permissible level of the EEVA of radon is 200 Bq/m^3 [13]. Among all sources of natural radioactivity, the main contribution to the annual effective dose of radiation to the population is made by radioactive gas, radon. Employees of the Institute of Radiobiology and Radiation Protection in the settlements of Aksu, Shantobe of the Akmola region, and Saumalkol of the North Kazakhstan region measured the EEVA of radon in residential premises in two seasons (winter and summer). In the summer period, the average EEVA of radon in residential and administrative premises of the settlement of Aksu was 144.3 Bq/m^3, Shantobe 36.4 Bq/m^3, Saumalkol 399.2 Bq/m^3, with a standard value of 200 Bq/m^3. In winter, the highest radon levels were recorded in the settlements of Saumalkol and Aksu, where the exceedances were 45 and 24 times, respectively. A clear correlation was observed between the radon concentration and the presence of cellars, ventilation levels, and seasonal temperature fluctuations, which underscores the need for continuous monitoring and the development of measures to reduce radon levels.

The results of the radon concentration analysis (EEVA) and the corresponding effective dose rate (EDR) presented in the figure are average values for all measurements taken in each settlement (Fig.5). In most of the studied samples, the EEVA values are within the permissible level (less than 200 Bq/m^3), and the EDR values are within the natural radiation background. However, there were anomalous zones that demonstrated a significant excess of both the average radon concentration (over 400 Bq/m^3) and the effective dose rate (over 0.30 μSv/h). However, the data shows sharp changes in values, with significant spikes, which suggests the presence of very high radon concentrations found in residential and administrative buildings.

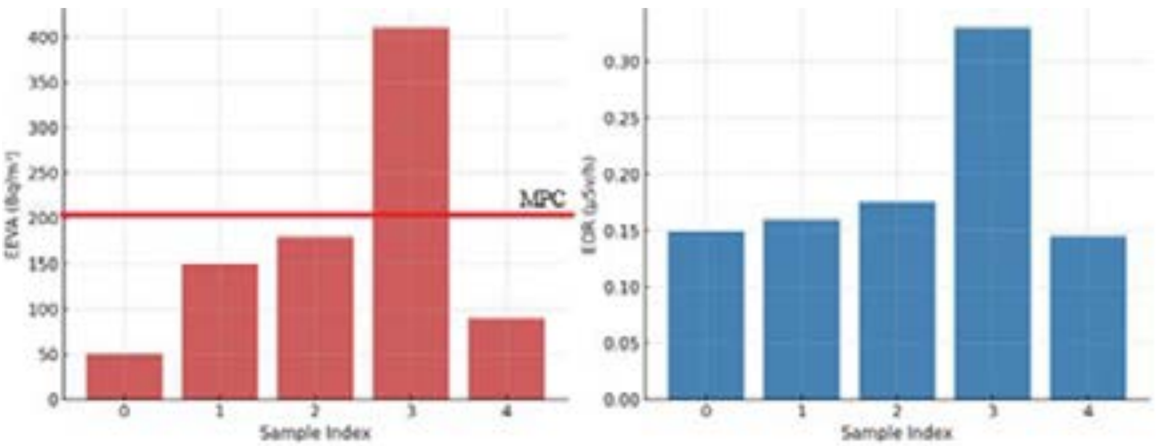

Figure 5. Regression function graph of North Kazakhstan settlements

The analysis of soil samples showed elevated levels of radionuclides, particularly ^{226}Ra and ^{232}Th. Worldwide range of radium-226: 12-120 Bq/kg, potassium-40: 100-1200 Bq/kg (UNSCEAR 2000). In the settlements of Shantobe and Aksu, the activity of ^{226}Ra exceeds the norm by 3.6 and 7.5 times, respectively, while in Saumalkol, the content of ^{232}Th was found to be 1.4 times higher than the permissible limits. The main factors contributing to this level of contamination are the residual effects of uranium and gold mining, as well as the possible use of radioactive contaminated materials in construction.

The water study revealed a significant exceedance of total alpha activity in water sources used by the population. The highest levels of radiation contamination were found in the wells of Saumalkol, where the exceedance of permissible values reached up to 7.6 times. In Shantobe, the exceedance was 1.6 times. However, it is worth noting that these waters are not used for drinking by the population but for livestock watering and garden irrigation. Nevertheless, this highlights the need for the implementation of filtration and purification systems, as well as more careful monitoring of the water supply.

Water samples were taken from wells and boreholes in the territories of the settlements. In the water samples taken from wells in the settlements of Saumalkol, the level of total alpha activity varies from 0.32 Bq/dm^3 to 1.53 Bq/dm^3, while the total beta activity ranges from 0.05 Bq/dm^3 to 0.90 Bq/dm^3. In the settlement of Novoukraintse, the water samples from a well (4 meters deep), located 2 km from the deposit, show that total alpha activity exceeds the permissible limit for drinking water by up to 7.6 times. The residents of these settlements consume water for drinking from both wells and a centralized supply. In the water samples collected from wells in the settlements of Aksu and Shantobe, the total alpha activity varied from 0.14 to 0.32 Bq/dm^3, while the total beta activity ranged from 0.18 to 0.24 Bq/dm^3. In the water sample from Shantobe, the level of alpha activity exceeded the permissible limit for drinking water by up to 1.6 times.

2. Radiation Situation in the Territories of Settlements Located Near Uranium Deposits in Southern Kazakhstan

During gamma scanning, the EDR of gamma radiation in the sanitary protection zones (SPZ) of the deposits varied from 0.06 to 0.10 μSv/h, which corresponds to the background value of the area. However, a radioactive contaminated site was identified in the area of the Mynkuduk uranium deposit, where EDR reached up to 0.56 μSv/h. In the settlements of Taukent, Taikonur, Shu, Zhuantobe, and Tasty in the Turkestan region, the average EDR is 0.08 μSv/h, which is within the background levels.

The values of EEVA in the settlements are as follows: in Taukent, it ranges from 5 to 160 Bq/m^3; in Zhuantobe, from 1 to 35 Bq/m^3; in Tasty, from 3 to 180 Bq/m^3; in Qylty, from 4 to 62 Bq/m^3; and in Shu, from 4 to 191 Bq/m^3, with the republican maximum permissible value being 200 Bq/m^3 [13]. The presented graphs reflect the average values of radon concentration in the air and the corresponding effective annual dose of radiation to the population in five settlements (Fig.6). According to the data obtained, in all samples the radon concentration is below the maximum permissible level (MPC = 200 Bq/m^3). Also, the calculated values of the effective annual dose of radiation (EDR) in all settlements do not exceed the background level (less than 0.10 μSv/hour). Thus, based on the analysis results, it can be concluded that the radiation situation in the surveyed settlements is within the permissible values. However, it should be emphasized that these are the results of only the summer season, the studies will be continued and monitoring will be carried out in other seasons.

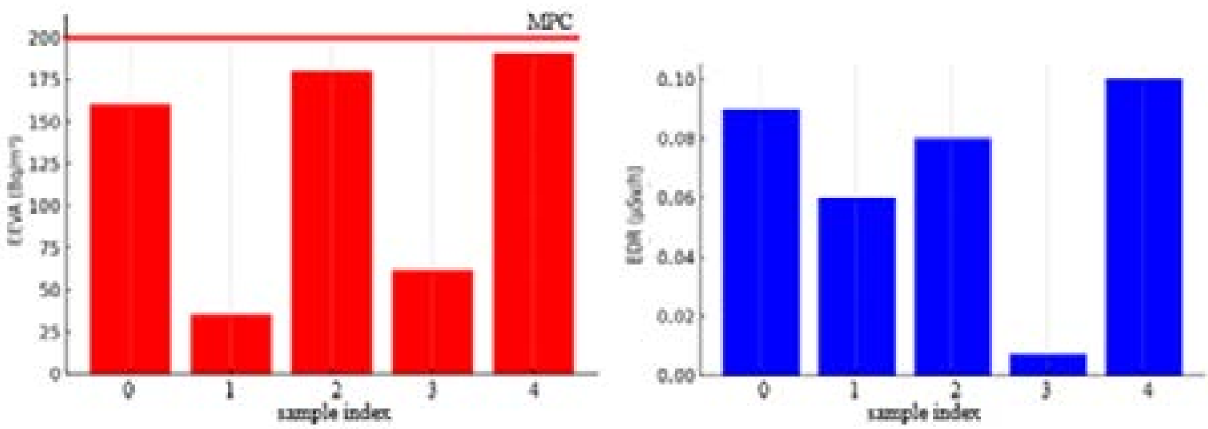

Figure 6. of South Kazakhstan settlements

In the soil samples taken from the settlements, the specific activity of natural radionuclides did not exceed the average national values and was within the permissible limits. Additionally, samples were collected from a radioactive-contaminated site. The analysis revealed that the specific activity of radium-226 was 1729.6±173 Bq/kg, and potassium-40 was 746.6±274.3 Bq/kg. Worldwide range of radium-226: 12–120 Bq/kg, potassium-40 : 100-1200 Bq/kg (UNSCEAR 2000). The radium-226 value exceeds the average national value by 14.4 times, which necessitates further research to clarify the sources of contamination, assess its continued impact on the ecosystem and public health, and develop measures to minimize radiation exposure risks.

Water samples were taken from settlements and nearby rivers, such as the Sarysu and Shu rivers. During the study, 11 artesian wells were identified, and samples were collected for analysis. The study of water samples from settlements and rivers showed an average value of total alpha- and beta-emitting radionuclides, $\alpha = 0.03$ and $\beta = 0.05$. The results of the radiometric analysis of the artesian wells showed that the total activity of alpha- and beta-emitting radionuclides in the water ranged from $\alpha = 0.01$ to $\alpha = 0.05$ Bq/dm^3 and from $\beta = 0.02$ to $\beta = 0.07$ Bq/dm^3. The values of total activity in water samples taken in populated areas and along the Sarysu and Shu rivers did not exceed the maximum permissible value for alpha activity=0.2 and beta activity=1.

Discussion

According to the studies conducted in the territories of settlements near the decommissioned uranium mines and radioactive waste storage sites, there is much more pronounced contamination of the air (EDR), as well as soil, water, and radon levels. This is associated with the history of uranium mining and the use of radioactive building materials. In particular, in some settlements such as Saumalkol and Aksu, the radon concentration exceeds the permissible limits by several dozen times, indicating serious contamination. High levels of alpha activity in non-potable water have also been recorded. At the same time, soil contamination data show that the activity of radionuclides ^{226}Ra and ^{232}Th in certain localized areas of the settlements exceeds the average national values, which may be linked to the residual effects of uranium and gold mining. It should be noted that uranium mining in the decommissioned uranium mines was carried out using the underground mining method, which is considered more environmentally harmful and leaves behind tailings. Thus, the studies reveal radiation contamination, requiring measures to minimize radiation exposure, such as stricter control over building materials and radon monitoring in residential buildings.

The radiation situation in the Shu-Sarysu uranium province and the nearby settlements is more stable. EDR in most of the settlements remains within background levels, with only a localized area near the Mynkuduk uranium deposit showing elevated gamma radiation levels. Radon concentrations in the air also vary, but overall remain within permissible limits, except in isolated cases. Water from rivers such as the Sarysu and Shu does not show significant radiation contamination, although further monitoring is required. Soil samples from the radioactive-contaminated site showed significant radiation activity, which requires further analysis. It should also be noted that uranium mining by the in-situ leaching method (ISL) impacts environmental contamination, especially of groundwater. The uranium left in the soil may remobilize, leading to the "rebound effect," which temporarily increases the amount of uranium released over a short period, creating a risk of further groundwater contamination[14-16].

Conclusion

Based on the studies conducted in settlements located near the uranium province of Northern Kazakhstan, the radon EEVA and EDR indicators are generally within the normal range, but there are anomalous areas that were found in the territories of the villages of Saumalkol and Aksu, where the radon concentration and alpha activity of water exceed the permissible limits. At the moment, uranium mines located in these territories are mothballed. However, the use of materials from the territories of mothballed uranium mines contributes to the excess of permissible values. The radiation situation in the Shu-Sarysu uranium province is more stable, and the radiation values remain within the background values. However, the in-situ leaching (ISL) method for extracting uranium can also create long-term environmental risks, such as uranium remobilization, leading to groundwater pollution. And this requires additional research. In the future, research will be continued on the complete radiochemical analysis of self-flowing wells and drinking water in the territories of the Shu-Sarysu province and nearby settlements.

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The contribution of the authors

Bakhtin M. – conceptualization, project administration, supervision;

Kashkinbayev Ye. – methodology, data curation;

Aumalikova M. – laboratory analysis, resources, writing – original draft;

Ibrayeva D. – data acquisition, validation;

Tazhedinova A. – literature review;
Altayeva N. – literature review, editing;
Zhaumitbay S. – sampling.

The authors have no conflict of interest to declare, as all sources used were duly cited and acknowledged.

References

1. D. Ibrayeva, M. Bakhtin, Y. Kashkinbayev et al., *Radiation situation in the territories affected by mining activities in Stepnogorsk areas, Republic of Kazakhstan: pilot study, Radiat Prot Dosimetry* 189(4): pp.517-526(2020). DOI: https://doi.org/10.1093/rpd/ncaa068

2. A.V. Boytsov, *Development of the Global Uranium Industry – Challenges of the Time, Proceedings of the Fifth International Symposium* "Uranium: Geology, Resources, Production": p. 11-22 (2021)

3. P.Kazymbet, A.Belonog, B.Imasheva, M.Bakhtin, M.Asylbekov, L.Ponyavina, V.Kurokhtin, *Comprehensive Radioecological Study of Uranium Mining Areas and Neighboring Settlements in Northern Kazakhstan*, Astana Medical Journal 3: p. 61-65 (2005)

4. *Decree of the Government of the Republic of Kazakhstan "On the Approval of the Program for the Conservation of Uranium Mining Enterprises and the Elimination of the Consequences of Uranium Ore Development for 2001-2010*": approved on July 25, 2001, No. 1006, Legal Reference System "Yurist" (2002).

5. F. Bekenova, S. Baydurin, A. Klodzinskiy, Z.Agibaeva *Increase in Relative Risks of Major Chronic Noncommunicable Diseases Under Prolonged Radiation-Chemical Exposure,* Astana Medical Journal 7(43): p. 140-142(2007)

6. R.Havránková, *Biological effects of ionizing radiation, Cas Lek Cesk*. Winter 159(7-8): p.258-260 (2020)

7. A. Ulanowski, J.C. Kaiser, U. Schneider, L. Walsh, *Lifetime radiation risk of stochastic effects – prospective evaluation for space flight or medicine,* Ann ICRP 49(1_suppl): p.200-212 (2020). DOI: https://doi.org/10.1177/0146645320956517

8.E.A. Domina, O.L. Kopylenko, V.F. Chekhun*, Evaluation of current factors of radiation-associated carcinogenesis.* Exp Oncol. 11: p.151-160 (2023). DOI: 10.15407/exp-oncology.2023.02.151

9. I. Kulhanova, A. Znaor, K.D. Shield, M. Arnold, J. Vignat, M. Charafeddine, I. Fadhil, H. Fouad, A. Al-Omari, A. Saeed Al-Zahrani, A. El-Basmy, A. Shamseddine, F.I. Bray, I. Soerjomataram, *Proportion of cancers attributable to major lifestyle and environmental risk factors in the Eastern Mediterranean region.* International Journal of Cancer. Volume 146(3): p.646-656(2019). DOI: 10.1002/ijc.32284

10. A.F.Malenchenko, S.N.Sushko, A.S.Shaforost, *Mutagenic and Tumorigenic Effects of Natural Uranium, Proceedings of the National Academy of Sciences of Belarus*. Biological Sciences Series 3: p. 111-118 (2011)

11. *Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data,* IAEA-TECDOC-1363, IAEA (2003)

12. ASTM D6327; *10 Standard Test Method for Determination of Radon Decay Product Concentration and Working Level in Indoor Atmospheres by Active Sampling on a Filter. ASTM International*: West Conshohocken (2016)

13. *On Approval of the Sanitary Rules "Sanitary and Epidemiological Requirements for Radiation-Hazardous Facilities",* Order of the Minister of Health of the Republic of Kazakhstan No. QR DSM-90(2022)

14. E.Ruedig, T.E. Johnson, *An evaluation of health risk to the public as a consequence of in situ uranium mining in Wyoming,* USA, Journal of Environmental Radioactivity 150(215): p.170-178(2015)

15. R. M.Tripathi, S. K.Sahoo, V.N. Jha, A. H.Khan, V.D. Puranik, *Assessment of environmental radioactivity at uranium mining, processing and tailings management facility at Jaduguda,* India, Applied Radiation and Isotopes 66(11): p.1666-1670 (2008)

16. *Contamination Risks Associated with In situ-Recovery Mining for Uranium,* available at: https://websites.umass.edu/natsci397a-eross/contamination-risks-associated-with-in-situ-recovery-mining-for-uranium/] (date of application: 03.02.2025)

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Қазақстандағы уран өндірудің радиациялық деңгейге әсері: екі уран провинция мысалындағы зерттеу

Аңдатпа. Бұл жұмыста Солтүстік Қазақстан және Шу-Сарысу уран провинциялары маңында орналасқан елді мекендердегі радиациялық жағдайға салыстырмалы бағалау жүргізілді. Көлікті гамма-спектрометрия, жаяу далалы гамма-түсірілім және радон мониторингін қолдану әдістері арқылы гамма-сәулелену деңгейлері, радонның тепе-тең көлемдік белсенділігі, сондай-ақ топырақ пен су сынамаларының радиоспектрометриялық талдауының нәтижелері зерттелді. Қосымша түрде зерттеліп отырған аумақтардағы радиациялық көрсеткіштердің кеңістіктік біркелкі еместігінің себептерін және ықтимал экологиялық қауіп аймақтарын анықтау мақсатында жергілікті геологиялық-гидрогеологиялық жағдайлардың, климаттық факторлардың және ұзақ уақыт жүргізілген тау-кен өндіру қызметінің әсері қарастырылды. Жасалынған зерттеу нәтижелері көрсеткендей, Солтүстік Қазақстан және Шу-Сарысу уран провинцияларының жанында орналасқан елді мекендердегі радиациялық фон жалпы алғанда нормативтік деңгейден аспайтыны анықталшды. Алайда, кейбір аумақтарда радонның теңдік көлемдік белсенділігінің нормалық деңгейден асуы байқалды, сондай-ақ Солтүстік Қазақстан өңіріндегі елді имекендердің бірқатар аумақтарында санитарлық нормадан жоғары көрсеткіштер тіркелді. Жекелеген топырақ және су сынамаларында табиғи радионуклидтердің шоғырлануының жоғарылауы анықталып, радиациялық әсердің техногендік немесе табиғи локализацияланған көздерінің бар екенін көрсетеді. Архивтік және қазіргі деректерді салыстыру кеңістіктік-уақыттық үрдістерді анықтауға, сондай-ақ қолданыстағы табиғатты қорғау және санитарлық шаралардың тиімділігіне объективті және жан-жақты ғылыми баға беруге мүмкіндік берді. Алынған нәтижелер жұмыс істеп тұрған және консервацияланған уран кен орындарының әсер аймақтарында халықтың денсаулығын сенімді қорғау, аумақтардың тұрақты әлеуметтік-экологиялық дамуын қамтамасыз ету және қоршаған ортаны ұзақ мерзімді сақтау үшін тұрақты, кешенді және жүйелі радиациялық мониторингтің қажеттілігін айқындайды.

Түйін сөздер: уран өндіру; радиациялық әсер; радон; радиациялық мониторинг; уран провинциясы

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Воздействие уранодобычи на радиационный уровень в Казахстане: исследование на примере двух урановых провинций

Аннотация. В данной сттатье представлена сравнительная оценка радиационной обстановки в населённых пунктах, расположенных вблизи Северо-Казахстанской и Шу-Сарысуйской урановых провинций. С использованием гамма-спектрометрии, пешеходной гамма-съемки и мониторинга радона проведена оценка уровней гамма-излучения, объемной равновесной объемной активности радона, а также результатов радиоспектрометрического анализа проб почвы и воды. Дополнительно рассмотрено влияние местных геолого-гидрогеологических условий, климатических факторов и последствий длительной горнодобывающей деятельности с целью выявления причин пространственной неоднородности радиационных показателей и потенциальных зон экологического риска в границах исследуемых территорий. Результаты показали, что в целом радиационный фон в населённых пунктах, расположенных вблизи Северо-Казахстанской и Шу-Сарысуйской урановых провинций, остаётся в пределах нормативных значений. Однако были выявлены аномальные участки с локальными превышениями объёмной активности радона, а в ряде населённых пунктов Северо-Казахстанского региона зафиксированы значения, превышающие установленные санитарные нормы. В отдельных пробах почвы и пробах воды было обнаружено превышение содержания природных радионуклидов, что свидетельствует о наличии локализованных источников радиационного воздействия техногенного или природного происхождения. Сопоставление с архивными и современными данными позволило выявить пространственно-временные тенденции, а также провести объективную и всестороннюю научную оценку текущей эффективности природоохранных и санитарных мероприятий. Полученные результаты подчёркивают необходимость постоянного, комплексного и системного радиационного мониторинга для надёжной защиты здоровья населения, устойчивого социально-экологического развития территорий и долгосрочной охраны окружающей среды в зонах влияния действующих и законсервированных урановых месторождений.

Ключевые слова: уранодобыча; радиационное воздействие; радон; радиационный мониторинг; урановая провинция.

References

1. D. Ibrayeva, M. Bakhtin, Y. Kashkinbayev et al., *Radiation situation in the territories affected by mining activities in Stepnogorsk areas, Republic of Kazakhstan: pilot study, Radiat Prot Dosimetry* 189(4): pp.517-526(2020). DOI: https://doi.org/10.1093/rpd/ncaa068

2. A.V. Boytsov, *Development of the Global Uranium Industry – Challenges of the Time, Proceedings of the Fifth International Symposium "Uranium*: Geology, Resources, Production": p. 11-22 (2021)

3. P.Kazymbet, A.Belonog, B.Imasheva, M.Bakhtin, M.Asylbekov, L.Ponyavina, V.Kurokhtin, *Comprehensive Radioecological Study of Uranium Mining Areas and Neighboring Settlements in Northern Kazakhstan,* Astana Medical Journal 3: p. 61-65 (2005)

4. *Decree of the Government of the Republic of Kazakhstan "On the Approval of the Program for the Conservation of Uranium Mining Enterprises and the Elimination of the Consequences of Uranium Ore Development for 2001-2010"*: approved on July 25, 2001, No. 1006, Legal Reference System "Yurist" (2002).

5.F. Bekenova, S. Baydurin, A. Klodzinskiy, Z.Agibaeva *Increase in Relative Risks of Major Chronic Non-communicable Diseases Under Prolonged Radiation-Chemical Exposure*, Astana Medical Journal 7(43): p. 140-142(2007)

6.R.Havránková, *Biological effects of ionizing radiation*, Cas Lek Cesk. Winter 159(7-8): p.258-260 (2020)

7. A. Ulanowski, J.C. Kaiser, U. Schneider, L. Walsh, *Lifetime radiation risk of stochastic effects - prospective evaluation for space flight or medicine,* Ann ICRP 49(1_suppl): p.200-212 (2020). DOI: https://doi.org/10.1177/0146645320956517

8. E.A. Domina, O.L. Kopylenko, V.F. Chekhun, *Evaluation of current factors of radiation-associated carcinogenesis.* Exp Oncol. 11: p.151-160 (2023). DOI: 10.15407/exp-oncology.2023.02.151

9. I. Kulhanova, A. Znaor, K.D. Shield, M. Arnold, J. Vignat, M. Charafeddine, I. Fadhil, H. Fouad, A. Al-Omari, A. Saeed Al-Zahrani, A. El-Basmy, A. Shamseddine, F.I. Bray, I. Soerjomataram, *Proportion of cancers attributable to major lifestyle and environmental risk factors in the Eastern Mediterranean region.* International Journal of Cancer. Volume 146(3): p.646-656(2019). DOI: 10.1002/ijc.32284

10. A.F.Malenchenko, S.N.Sushko, A.S.Shaforost, *Mutagenic and Tumorigenic Effects of Natural Uranium, Proceedings of the National Academy of Sciences of Belaru*s. Biological Sciences Series 3: p. 111-118 (2011)

11. *Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data*, IAEA-TECDOC-1363, IAEA (2003)

12*. ASTM D6327; 10 Standard Test Method for Determination of Radon Decay Product Concentration and Working Level in Indoor Atmospheres by Active Sampling on a Filter. ASTM International*: West Conshohocken (2016)

13. *On Approval of the Sanitary Rules "Sanitary and Epidemiological Requirements for Radiation-Hazardous Facilities", Order of the Minister of Health of the Republic of Kazakhstan No.* QR DSM-90(2022)

14. E.Ruedig, T.E. Johnson, *An evaluation of health risk to the public as a consequence of in situ uranium mining in Wyoming, USA, Journal of Environmental Radioactivity* 150(215): p.170-178(2015)

15. R. M.Tripathi, S. K.Sahoo, V. N. Jha, A. H.Khan, V. D. Puranik, *Assessment of environmental radioactivity at uranium mining, processing and tailings management facility at Jaduguda,* India, Applied Radiation and Isotopes 66(11): p.1666-1670 (2008)

16. *Contamination Risks Associated with In situ-Recovery Mining for Uranium,* available at: https://websites.umass.edu/natsci397a-eross/contamination-risks-associated-with-in-situ-recovery-mining-for-uranium/] (date of application: 03.02.2025)

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