

**General Methodology for Assessing the Content
of Artificial Radionuclides in Livestock Products
Produced in Areas Polluted by Nuclear Tests**

Doctoral (PhD) thesis

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Introduction

The Semipalatinsk Test Site (STS) in northeastern Kazakhstan, active from 1949 to 1989, was one of the most significant nuclear testing grounds of the Soviet Union. Covering approximately 18,300 square kilometers, it witnessed 456 nuclear tests, leading to extensive radioactive contamination. Despite the site's closure, unauthorized agricultural activities have continued, raising concerns about the transfer of radionuclides like ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, and ^{241}Am into livestock products consumed by local populations. This dissertation aims to assess the content and transfer parameters of these radionuclides in livestock and poultry products, providing essential data for evaluating the risks associated with consuming contaminated foodstuffs. By focusing on the unique environmental conditions and contamination sources at the STS, this research contributes to the development of predictive models and guidelines for safe agricultural practices in contaminated areas, ultimately supporting public health and safety in regions affected by nuclear activities.

Aim

The aim of this work is to develop a methodology for assessing the transfer of artificial radionuclides into livestock products from contaminated areas. To this end, I have investigated the relevant transfer parameters for key radionuclides in livestock and poultry. Finally, by analyzing these findings, I propose a comprehensive approach for evaluating the radiological safety of animal-derived food products in nuclear-affected regions.

Materials and methods

The study was conducted at the STS using horses and broilers as experimental subjects. Animals were divided into groups and fed contaminated soil and feed, with radionuclide levels of ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, and ^{241}Am monitored. Tissue samples were collected and analyzed using gamma spectrometry and radiochemical techniques to determine radionuclide concentrations. Control samples were also taken from uncontaminated areas. The experimental setup aimed to simulate real-world conditions of radionuclide exposure in livestock, providing data on the transfer and accumulation of radionuclides in animal tissues and food products.

Results

The results of this study focused on assessing the transfer of artificial radionuclides, specifically ^{137}Cs , ^{90}Sr , $^{239+240}\text{Pu}$, and ^{241}Am , into livestock and poultry products from contaminated areas at the STS.

The experiments conducted on horses revealed that radionuclide transfer varies with age; younger animals, such as yearling fillies, exhibited higher transfer rates for ^{137}Cs and ^{90}Sr compared to adults. This indicates an age-dependent accumulation pattern, with potential implications for the safety of consuming products from younger livestock.

In addition, the study demonstrated that the radionuclide transfer into fetal tissues was significant, particularly for $^{239+240}\text{Pu}$ and ^{241}Am . This finding highlights the potential risks for offspring born to animals grazing in contaminated areas, emphasizing the importance of monitoring prenatal exposure in assessing long-term health impacts on livestock populations.

Broiler studies showed that the accumulation dynamics of ^{137}Cs and ^{241}Am differ across tissues, with muscle, liver, and bone displaying distinct patterns. The muscle tissue showed relatively lower

accumulation of ^{241}Am , while the liver and bones had higher concentrations, suggesting that certain tissues may pose greater risks for human consumption.

The study also assessed the impact of long-term exposure to contaminated feed. Results indicated that radionuclide accumulation in broilers stabilizes over time, with a plateau in ^{137}Cs and ^{241}Am levels observed after several weeks. This suggests that initial exposure levels are crucial in determining long-term accumulation, and continuous exposure may not lead to proportionally higher radionuclide content in tissues.

Finally, the data gathered from these experiments were used to refine predictive models for assessing radiological safety in livestock products. These models take into account the variability in radionuclide transfer across different species, ages, and tissue types, providing a more comprehensive framework for evaluating the risks associated with consuming animal products from contaminated areas.

Theses of the PhD Dissertation

Thesis 1.:Radionuclide Transfer and Retention: My studies highlight that the transfer of ^{241}Am , ^{137}Cs , ^{90}Sr , and $^{239+240}\text{Pu}$ to animal tissues varies significantly depending on the source of contamination (soil vs. contaminated feed). For horses, the highest transfer coefficients (F_f) were observed in the liver of mares fed leachate-contaminated feed, with values reaching $(72\pm 22) \times 10^5 \text{ d kg}^{-1} \text{ FW}$ for ^{241}Am and $(31.8\pm 8) \times 10^5 \text{ d kg}^{-1} \text{ FW}$ for $^{239+240}\text{Pu}$. In fillies, the highest value for ^{137}Cs was $35.3 \times 10^{-3} \text{ d kg}^{-1} \text{ FW}$, while for ^{90}Sr , the highest was recorded in the ribs, reaching $(720\pm 144) \times 10^{-3} \text{ d kg}^{-1} \text{ FW}$. These findings include pioneering data for ^{241}Am and $^{239+240}\text{Pu}$ transfer coefficients in horse meat at the STS, marking the first such reports both locally and globally. The IAEA handbook (2010) does not provide transfer coefficient values for horses, making this study a significant contribution to the understanding of actinide transfer in livestock.

Thesis 2.:Transfer Parameters: The transfer parameters of radionuclides ^{137}Cs and ^{90}Sr into the organs and tissues of yearling fillies were found to be higher than in adults by up to 1.6 and 3.6 times, respectively. However, I have found that age does not appear to significantly affect the accumulation of $^{239+240}\text{Pu}$ and ^{241}Am in horse tissues. In broilers, the Transfer Coefficient for ^{137}Cs in muscle from the grass meal diet was significantly higher at $(192.9\pm 25.8) \times 10^{-2} \text{ d kg}^{-1} \text{ FW}$, compared to $(18.8\pm 4.6) \times 10^{-2} \text{ d kg}^{-1} \text{ FW}$ from soil contamination. For ^{241}Am , the Transfer Coefficient in muscle was $(1.1\pm 0.95) \times 10^{-4} \text{ d kg}^{-1} \text{ FW}$.

Thesis 3.:Dynamics of Accumulation: I have identified for the first time the accumulation dynamics of ^{137}Cs and ^{241}Am in broilers using contaminated feed from the STS territory. The study observed dynamic equilibrium stages for ^{137}Cs in broilers' muscle by the 30th day and in their liver and bone by the 14th day of feeding. For ^{241}Am , the muscle reached equilibrium immediately, while the liver and bone took longer to stabilize, with significant accumulation over the study period.

Thesis 4.:Excretion Dynamics: I have identified for the first time the excretion dynamics of ^{137}Cs and ^{241}Am in boilers using contaminated feed from the STS territory. The excretion of ^{137}Cs from broiler muscle, liver, and bone followed an exponential decay, characterized by an initial rapid phase followed by a slower phase. The majority of ^{137}Cs was excreted within the first week. Specific equations were used to model the excretion kinetics for each organ. By the 70th day, 20-50% of the initial ^{241}Am concentration remained in the liver, while approximately 35% persisted in the bone, demonstrating a more stable retention in bone compared to a gradual decline in the liver.

Thesis 5.:Soil as a Contamination Source: In areas with ground nuclear test epicenters, such as the STS, I have found that soil directly serves as a significant source of radionuclide contamination in livestock products, which pathway should be incorporated into international best practices. Updated data indicate that for horse meat, soil is the dominant source of $^{239+240}\text{Pu}$ and ^{241}Am , contributing 92.8% and 93.2%, respectively, while the contribution from forage is substantially lower at 7.2% and 6.8%. Conversely, ^{137}Cs contamination in horse meat is primarily from forage (87.2%), with soil contributing only 12.8%. For ^{90}Sr , the distribution is more balanced, with 57.0% from soil and 43.0% from forage.

Thesis 6.:Food Safety Implications: The findings provide critical data for estimating internal radiation doses from the consumption of livestock products in regions impacted by nuclear tests. I have identified that the high retention of ^{241}Am in bone tissue and liver, in particular, poses a potential long-term risk to consumers, emphasizing the importance of monitoring and mitigating contamination in nuclear-affected regions.

LIST OF PUBLICATIONS

Publications that pose the base of the dissertation

1. **Baigazinov ZhA**, Lukashenko SN, Panitsky AV, et al. (2020). The transfer of $^{239+240}\text{Pu}$, ^{241}Am , ^{137}Cs and ^{90}Sr to the tissues of horses. *J of Env Radioactivity* (WoS Q3, Impact Factor 2.161) doi.org/10.1016/j.jenvrad.2020.106322
2. Mamyrbayeva AS, **Baigazinov ZhA**, Lukashenko SN, et al. (2021) The excretion of ^{241}Am and ^{137}Cs from the broilers organs after long-term application. *J of Env Radioactivity* (WoS Q3, Impact Factor 2.161) [doi:10.1016/j.jenvrad.2021.106543](https://doi.org/10.1016/j.jenvrad.2021.106543)
3. Mamyrbayeva AS, **Baigazinov ZhA**, Lukashenko SN, et al. (2020). The transfer of ^{241}Am and ^{137}Cs to the tissues of broilers' organs. PLoS ONE. (WoS Q1, Impact Factor 2.740) doi.org/10.1371/journal.pone.0235109

Other publications, not tightly connected to the dissertation

2024

1. Kozhakhhanov T.E., Larionova N.V., Lukashenko S.N., **Baigazinov, Zh.A.**, Kabdyrakova, A.M., Kunduzbayeva, A.Y.. (2024) Peculiarities in accumulation of radionuclides by fruit and berry trees and shrubs, Journal of Environmental Radioactivity, <https://doi.org/10.1016/j.jenvrad.2023.107317> (*WoS Q3, Impact Factor IF 2.161*)
2. Mukhamediyarov NZ, Makarychev S V., Umarov MA, **Baigazinov Zh.A.**, et al. Uranium speciation and spatial distribution in the bottom sediments along the Uzynbulak creek at the Semipalatinsk test site. J Radioanal Nucl Chem. Published online 2023. <https://doi:10.1007/s10967-023-09117-7> (*WoS Q2, Impact Factor 1.6*)

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3. **Baigazinov Z**, Lukashenko S, Silybayeva B, et al. The transfer of ¹³⁷Cs and heavy metals to tissues within the organs of snails. Sci Rep. 2023;13(1). <https://doi:10.1038/s41598-023-42580-6> (*WoS Q2, Impact Factor 4.6*)

2022

4. J. Guillén, N.A. Beresford, **Zh Baigazinov**, A. Salas, A. Kunduzbaeva (2022) Can stable elements (Cs and Sr) be used as proxies for the estimation of radionuclide soil-plant transfer factors?, Environmental Pollution, 299, 118897 <https://doi.org/10.1016/j.envpol.2022.118897> (*WoS Q1, Impact Factor 8.071*)
5. Kenzhina L, Aigul Mamyrbayeva A, Lukashenko S, **Baigazinov Zh.**, Biyakhmetova D, Panitskiy A, Polivkina E, Zhamaldinov F, Patrono C, Palma V, Testa A. (2022) Background Level of Unstable Chromosome Aberrations in the Kazakhstan Population: A Human Biomonitoring Study, International Journal of Environmental Research and Public Health, <https://doi.org/10.3390/ijerph19148485> (*WoS Q2, Impact Factor 4,798*)

2021

6. Geras'kina S, Minkenova K, Perevolotsky A, **Baigazinov Zh**, Perevolotskaya T, (2021) Threshold dose rates for the cytogenetic effects in crested hairgrass populations from the Semipalatinsk nuclear test site, Kazakhstan. *J. of Hazardous Materials* (*Q1, Impact Factor 10.038*) <https://doi.org/10.1016/j.jhazmat.2021.125817>
7. Geras'kin S.A., Minkenova K.S., Perevolotsky, A.N. **Baigazinov Zh.A.**, Perevolotskaya T.V., (2021) Nonlinear relationship between Sr-90 content in the Koeleria gracilis plants growing in the Semipalatinsk test site and frequency of cytogenetic alterations. «Radiation and Risk», 2021, vol. 30, No. 2, pp.77-88 [DOI: 10.21870/0131-3878-2021-30-2-77-88](https://doi.org/10.21870/0131-3878-2021-30-2-77-88) (*CiteScore 1,0, 20%*)

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8. Inaba J, Ishida J, Hirota S, Yoshinaga S, Kusumi S, **Baigazinov Zh**, Berezina M. V, Benzina G. T, Berezin S. A, & Ogiu T. Dose Reconstruction for Residents Near the Former Semipalatinsk Nuclear Test Sites with a Focus on the Study of Radiation Health Effects *Japanese Journal of Health Physics*, 2020, Environmental Science / Health, Toxicology and Mutagenesis [DOI: 10.5453/jhps.55.250](https://doi.org/10.5453/jhps.55.250) (CiteScore 0,3 10%)
9. Minkenova KS, **Baigazinov ZA**, Geras'kin SA, Perevolotsky AN. Cytogenetic Effects in Crested Hairgrass from a Site Where Tests of Military Radioactive Substances Were Conducted at the Semipalatinsk Test Site. *Biol Bull.* Published online 2020. [doi:10.1134/S1062359020120067](https://doi.org/10.1134/S1062359020120067) (*WoS Q4, Impatfactor 0.413*)

Presentations in English

2024

1. **Baigazinov Zh.**, Novák M., Csordás A., et al. (2024) Radon exhalation rate of soil samples from the Transdanubian region, Hungary. International Workshop on Radon Studies in Asia and Oceania. March 24-26, 2024. Shanghai, China

2023

2. **Baigazinov Zh.A.**, Lukashenko S.N., Silybayeva B.M., Bukabaeva Zh.T., Kovacs T. (2023) The transfer of ^{137}Cs and heavy metals to the tissues of snails' organs. Radiation Awareness and Detection in. Natural Environment. March 2-4, 2023, Dehradun, India
3. **Baigazinov Zh.A.**, Lukashenko S.N., Kovacs T. (2023) General methodology for assessment the content of artificial radionuclides in livestock products produced in areas polluted by nuclear tests International Symposium on Natural and Artificial Radiation Exposures and Radiological Protection Studies September 19-22, 2023, Hirosaki, Japan
4. **Baigazinov Zh.A.**, Lukashenko S.N., Karatayev S.S., Mamyrbayeva A.S., Baigazy S.A., Panitsky A.V., Bazarbaeva A.M., Hegedus M., Kovacs T.(2023) $^{239+240}\text{Pu}$, ^{241}Am , ^{137}Cs and ^{90}Sr Radionuclide Uptake in Equines site the 15th Vietnam Conference on Nuclear Science and Technology, August 9-11, 2023, Nha Trang, Khanh Noa, Viet Nam

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5. **Baigazinov Zh.A.**, Lukashenko S.N., Toth-Bodrogi E., Kovacs T. (2022) Assessment of farm animal breeding possibility on the Semipalatinsk test site 10 th Jubilee International Conference On Radiation In Various Fields Of Research (RAD 2022) 13–17.06.2022, Herceg Novi, Montenegro
6. **Baigazinov, Zh.A.**, Lukashenko, S.N., Kovacs T. (2022) Transfer parameters of radionuclide into farm animal products in Semipalatinsk test site condition (main results and prospects) Twelfth International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII) April 3 -8, 2022, Kailua-Kona, Hawaii

7. **Baigazinov Zh.A.**, Lukashenko S.N., Silybayeva B.M., Bukabaeva Zh.T., Kovacs T. (2022) The transfer of ^{137}Cs and heavy metals to the tissues of snails' organs VIII. Terrestrial Radioisotopes in Environment International Conference on Environmental Protection 4-7 October 2022 Vonyarcvashegy, Hungary
8. Panitsky A.V., **Baigazinov Zh.A.**, Bayserkenova T.N., Baigazy S.A. Alexandrivich I.A. (2022) Assessment of ^{137}Cs , ^{90}Sr , ^{241}Am , $^{239+240}\text{Pu}$, ^3H (HTO, OBT) concentrations in the fish from nuclear shell craters and rivers of Semipalatinsk test VIII. Terrestrial Radioisotopes in Environment International Conference on Environmental Protection 4-7 October 2022 Vonyarcvashegy, Hungary
9. Mukhamediyarov N.Zh., Makarychev S.V., Umarov M.A., Dyusembaeva M.T., Shakenov Ye.Z., Kolbin V.V., Yesilkanov G.M., Temirzhanova A.Ye., Tashekova A.Zh., Zhamaldinov F.F., Nurekenova A.N., Sapakova A. K., **Baigazinov Zh.A.**, Kovacs T. (2022) Uranium speciation and spatial distribution in the bottom sediments along the Uzynbulak creek at the Semipalatinsk Test Site VIII. Terrestrial Radioisotopes in Environment International Conference on Environmental Protection 4-7 October 2022 Vonyarcvashegy, Hungary
10. Kenzhina L.B., **Baigazinov Zh.A.**, Lukashenko S.N., Mamyrbayeva A.N. (2022) Determination of the regional background frequency of stable translocations in population living in the territory adjacent to Semipalatinsk test site. VIII. Terrestrial Radioisotopes in Environment International Conference on Environmental Protection 4-7 October 2022 Vonyarcvashegy, Hungary

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11. **Baigazinov Zh.A.**, Baigazy S.A., Lukashenko S.N., Kovacs T. (2021) Transfer parameters of ^{90}Sr into the skeleton of farm animals Book of Abstracts Third National Conference On Radiation Awareness and Detection in- Natural Environment (RADNET III) MARCH 18-20, 2021 Organized by Department of Physics, Govt. P.G. College New Tehri, Tehri Garhwal & Department of Physics, H.N.B. Garhwal University Badshahi Thaul Campus, Tehri Garhwal In Collaboration with

12. Mamyrbayeva A, **Baigazinov Zh**, Lukashenko S, Kovács T (2020) The transfer of ^{241}Am and ^{137}Cs to the tissues of broilers' organs. The 3rd Workshop on Radiation Research and Its Related Issue 2020 & The 7th Educational Symposium on RADIATION AND HEALTH by young scientists Joint Symposium November 21-23, 2020 Hirosaki, Japan. Online. Acknowledgement: This research founded by the ISTC in the framework of the K – 2085 project <https://esrah2020info.wixsite.com/site>.

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13. L. Kenzhina, **Z. Baigazinov**, A. Mamyrbayeva, S. Lukashenko: Determination of the regional background frequency of stable translocations in population living in the territory adjacent to Semipalatinsk test site. VII. Terrestrial Radioisotopes in Environment. International Conference on Environmental Protection. University of Pannonia, Institute of Radiochemistry and Radioecology p. 44-45. ISBN 978-615-81632-0-0, DOI 10.18428/TREICEP-2020
14. S. Lukashenko, **Z. Baigazinov**: Semipalatinsk Test Site: current radioecological situation and prospects. VII. Terrestrial Radioisotopes in Environment. International Conference on Environmental Protection. University of Pannonia, Institute of Radiochemistry and Radioecology p. 96. ISBN 978-615-81632-0-0, DOI 10.18428/TREICEP-2020