Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(1): 2177 – 2185 (2025)
www.ejabf.journals.ekb.eg

Indication of Radioactive Contamination (Cs^{137}, Sr^{90}) in Freshwater Fish of the Irtysh River, Kazakhstan

Yermekkazy Bilyalov[1], Asem Myrzhiyeva[2], Zeinolla Tokayev[1], Aizhan Akhmetzhanova[1], Shyngys Suleimenov[1]*, Aliya Moltabayeva[1], Dauletbek Muratbayev[1]

[1] Veterinary Department, Faculty of Veterinary Medicine and Agricultural Management, Non-commercial joint-stock company "Shakarim University of Semey", Semey, the Republic of Kazakhstan

[2] Department of Biological Safety, Faculty of Veterinary Medicine, Kazakh National Agrarian Research University, Almaty, the Republic of Kazakhstan

*Corresponding Author: Shyngys2203@mail.ru

ARTICLE INFO

Article History:
Received: Oct. 24, 2024
Accepted: Dec. 29, 2024
Online: Feb. 17, 2025

Keywords:
Semipalatinsk test site, Radionuclides, Transposition, Freshwater fish, Environmental monitoring

ABSTRACT

The Semipalatinsk test site, one of the largest and the first nuclear test site on the territory of the USSR used until 1991, remains a large radioactive site with a constant threat. The content of Sr^{90} and Cs^{137} was addressed in freshwater fish caught in the Irtysh River. The purpose of the research was to determine the degree of activity of Cs^{137} and Sr^{90} in Bq/kg, which means the specific activity of the radionuclide-ratio of the activity of the radionuclide in the radioactive image to the mass of the sample. In the course of the study, a prospective uncontrolled study of radionuclide content (Sr^{90} and Cs^{137}) in muscle tissues of freshwater fish (62 samples) caught in the Shulba reservoir, tributaries, and the Irtysh River bed within the East Kazakhstan region, Zaisan Lake in the Kurchum coast was carried out. We found that the content of Sr^{90} [min 5.34; max - 20.76 Bq/kg] exceeded the content of Cs^{137} [min - 0.43; max - 2.96 Bq/kg] in hydrobionts caught in the Irtysh River, which may be associated with the peculiarities of circulation of each radionuclide in the environment, as well as the possibility of creating colaborative links between radionuclides and organic substances. Monitoring of hydrobiota radioactivity in field and artificial conditions is an important condition for the development of fish farming enterprises to ensure national food security and to create export potential of the Republic of Kazakhstan.

INTRODUCTION

Monged *et al.* (2020) fixed that environmental monitoring is an important part of environmental assessment of the state of the territory, in particular, of water bodies. For Kazakhstan, radionuclide distribution monitoring in natural objects has become essential due to active the use of the Semipalatinsk test site "S", in particular, monitoring of water bodies remains especially important due to the accumulation of large pollutions amounts in mule sediments **(Monged *et al.*, 2020; Lu *et al.*, 2021; Krivitskiy *et al.*, 2022)**.

Nuclear weapons testing and the operation of nuclear fuel cycle facilities have resulted in the release of over $1.8.8 \times 10^{24}$ Bq radioactive isotopes into the earth's

atmosphere. Thus, on the territory of Kazakhstan, at the S site, which covers an area of 18500km^2, 450 nuclear tests have been conducted over forty years of testing: ground, air and underground. This has led to the creation of a complex radiation situation on the territory of the Republic of Kazakhstan **(Krivitskiy *et al.*, 2022; Rzabay *et al.*, 2022)**.

Changes in the ecological situation in different regions also affect the condition of fishery reservoirs, veterinary and sanitary-hygienic well-being of freshwater fish, which may cause the spread of foci of both zooanthroponosis transmitted through fish and the accumulation of toxic elements in it - nitrogen-containing substances (ammonia, nitrates, nitrites), heavy metals, pesticides and radionuclides, the half-life of which takes a considerable period and significantly affects the condition of both hydrobionts and humans who consume fish products **(Beisenova, 2020; Shah & Parveen, 2020; Lehun *et al.*, 2021; Mamilov *et al.*, 2021)**.

Ensuring food safety of the country and quality imports in accordance with the country's commitments is an important task of the state veterinary and environmental services **(Kushkumbayev & Mussabekova, 2022)**. In this regard, studies to determine the general regularities of radioisotope concentration in the external environment and living organisms are actualised **(Kryshev *et al.*, 2021; Lehun *et al.*, 2021)**. Moreover, **Aidarkhanova *et al.* (2024)**, who studied the technogenic pollution of the Irtysh River basin, noted the need to conduct radiological studies of fish, which are used for food purposes, at the constant in this area.

Our research study aimed to determine the activity of Cs^{137} and Sr^{90} in Bq/kg, which means the specific activity of the radionuclide-ratio of the activity of the radionuclide in the radioactive image to the mass of the sample.

MATERIALS AND METHODS

A prospective non-controlled observation research was conducted in 2009 for the Irtysh River basin as a debut research of such direction. At this time, four field trips for taking the samples for research (hematological and radiological) were made.

- ✓ In April 2009 trip to Shulbinskoye reservoir
- ✓ In June and August route expeditions on Irtysh River (East Kazakhstan region)
- ✓ In July, Lake Zaisan in the Kurchum coast.

During the expeditions, 62 samples were taken for radiological studies, which were conducted by the Republican Veterinary Laboratory of the State Inspection Committee of the Agricultural Complex of the Republic of Kazakhstan (Semey).

All stages of the research have been reviewed by the bioethics committee of the Veterinary Medicine and Agricultural Management Faculty, Shakarim University of Semey (Protocol No. 3 from 21 November, 2023) and approved as being in accordance with the principles of the Declaration of Helsinki on Experiments Involving Living Subjects.

Radiological investigations

To determine the radioactive contamination of selected fish samples, the total beta activity, which reflects specific radioactivity (Ci/kg, Ci/L), was initially determined in the laboratory, which allowed quick obtaining of indicative information on the degree of radioactivity of the sample under study.

Radiochemical analysis was carried out to elucidate the isotopic composition of radionuclides in fish, which included the following operations:

- radioisotope release,
- purification and verification of its radiochemical purity,
- activity measurement (radiometry).

Based on the results obtained, an opinion on the level of radioactive contamination of the selected samples was created **(Mettler, 2013; Bratushkina *et al.*, 2018)**.

Data processing

The obtained data of radiological analysis were systematized with determination of absolute value (M) for each sample (group of samples), and the results were compared with 'Sanitary and epidemiological requirements for the protection of radiation safety' **(Minister of Health of the Republic of Kazakhstan, 2020)** and on approval of hygienic standards for ensuring radiation safety' **(Minister of Health of the Republic of Kazakhstan, 2022)**.

RESULTS

Indication (detection) of radioactive substances in fish is one of the important tasks of the veterinary service to prevent and avoid radionuclides from the external environment (through fish products) into the human body **(Mettler, 2013; Bratushkina *et al.*, 2018)**. An assessment of the toxic substances' cumulative impact on fish populations will allow the development of recommendations on the safe use of water resources for enterprises and organizations operating in water basins. During the study of samples caught in the Shulba and Bukhtarma reservoirs, as well as in the Irtysh River, exceedances of permissible norms of radioactive $Cs^{137\text{-}130}$ and $Sr^{90\text{-}100}$ were not detected in fish muscle tissues (Table 1).

Table 1. Evaluation of the fresh water fish radioactive pollution

Study place	Reservoir part	Fish type	Samples number, pcs	Radioactive pollution, Bq/kg*	
				Cs^{137}	Sr^{90}
Shulbinsk reservoir, Ulan District, East Kazakhstan					
Novo-Azov village	Kovalevka Bay	Bream	2	1.21	9.10
		Perch	2	1.70	8.05
		Roach	2	2.08	5.98
Betkuduk village	Kyzyl-Su Cape	Zander	6	2.04**	9.16**
		Bream	8	2.23**	10.172**

		Perch	2	1.89	9.18
Buhtamin reservoir, Kurchum District, East Kazakhstan					
Zelenoe village	Oiran region	Crucian carp	4	2.72	7.36
		Zander	1	2.52	13.3
		Bream	2	1.68	9.76
		Roach	2	2.96	7.28
		Perch	1	2.73	9.47
Irtysh River, East Kazakhstan Region					
Shemonaihinskiy District, Zevakino village	Channels of the Irtysh River	Bream	3	1.50	13.16
		Perch	1	0.82	20.76
		Roach	1	1.11	11.35
		Zander	2	0.43	13.02
Beskaragai District, Bodene village	Kobelevski y Zaton	Bream	6	1.69	8.51
		Zander	2	0.60	11.76
		Perch	2	0.83	14.07
		Roach	3	1.24	11.74
Beskaragai District, Semiyarka village	Irtysh River	Crucian carp	1	2.16	7.15
		Ruff	1	0.96	5.34
		Zander	1	2.42	9.64
		Bream	2	1.81	8.39
		Roach	2	2.2	9.86
		Perch	3	2.45	8.16

*Average value after independent testing of each sample of caught fish.

**The study was conducted on the average sample because of the same age and weight of the caught fish.

According to the results of sampling at all control points, the accumulation of Sr^{90} (half-life of 28.8 years) in the muscles of freshwater fish exceeded that of Cs^{137} (half-life of 30.2 years). It cannot be said that the radioactivity of fish in reservoirs is higher compared to that directly in the Irtysh River channel. At the same time, with regard to Sr^{90}, it is impossible to assert that predatory fish (pikeperch, perch, ruff) are less contaminated in comparison with fish feeding, among others, from mule sediments (roach, roach, crucian carp). The minimum concentration of Sr^{90} (5.34Bq/kg) was recorded in ruff caught in the Irtysh channel, while the maximum concentration of 20.76Bq/ kg was recorded in the Irtysh tributary near Zevakino village.

With respect to Cs^{137} content, predatory fish show some lower concentrations of this radionuclide in hydrobionts caught in the river channel compared to the reservoir (min value of 0.43 Bq/kg - tributary of the Irtysh River, pikeperch; max volume was of 2.96 Bq/kg - Bukhtarma reservoir, roach), although it is not possible to speak about a persistent trend given the fish caught near the Semiyarka village at the Beskaragai District (Table 1), which may be due to the peculiarities of topography and drainage.

DISCUSSION

Until today, the S site poses a significant threat to the ecology of the Republic of Kazakhstan, given the significant amount of radionuclides released (more than 100 Ci/km^2) into the atmosphere of the landfill over 40 years of its use **(Toropov, 2017; Toropov, 2018)**. Taking into account this fact, the veterinary and fishery sciences of Kazakhstan constantly monitor and strengthen scientific research on the development of diagnostic methods, prevention, as well as on the study of the impact of anthropogenic pollutants in the external environment and water bodies in particular **(Witeska *et al.*, 2022)**.

Aidarkhanova *et al.* (2024) noted in their research the neediness for the Irtysh River ecosystem's constant monitoring as transboundary - located on the territory of three states (Kazakhstan, China and Russia) - and strategic river for all Central Asian region. The authors claimed that the river is technogenic polluted and needs to be monitored not just for chemical pollution but to analyze the aquaculture state which is not presented. Sampling of freshwater fish was carried out in the Irtysh River (Fig. 1), the basin of which has been subjected to significant radiation contamination due to S site active using **(Krasnoyarova *et al.*, 2020)**.

Fig. 1. (A) Cartographic location of East Kazakhstan Oblast in Kazakhstan; **(B)** Semipalatinsk test site (S) and fish sampling sites for analysis (1-6) along the Irtysh River in East Kazakhstan Oblast

In the course of the study, the radioactivity of captured samples of freshwater fish was analyzed, both predators (pikeperch, ruff, perch) and fish of the carp family (roach, roach, crucian carp), whose food behavior involves passing mule sediments through the body. Pollutants accumulate in bottom sediments, where they are processed by small crustaceans. Radionuclides enter the tissues and bones of fish through the biological chains **(Shahjahan *et al.*, 2022; Witeska *et al.*, 2022)**. The actuality of the conducted research is also proved by **Aidarkhanova *et al.* (2024)**, who fixed the fact of the constant incoming radionuclides (H^3 in the main) in the Irtysh ecosystem even in winter due to the incoming Shagan River water.

The obtained data in the experiment can be used in monitoring the accumulation of pollutants (radionuclides), which allows us to assess not only the radioactivity of hydrobionts in the region, but also to assess the general ecological situation, which correlates with the data of **Shahjahan *et al.* (2022)**. They note that the state of the host organism is directly dependent on the state of the environment.

According to the obtained data, the content of the studied radioisotopes did not exceed the permissible norms (130 Bq/kg for Cs^{137} and 100 Bq/kg for Sr^{90}), established by the **Minister of Health of the Republic of Kazakhstan (2022)**. However, the content of Sr^{90} exceeded the content of Cs^{137} in all samples, which can be explained by the peculiarities of the stay of these radionuclides in the aquatic environment. Thus, according to **Toropov (2018)**, 97% of Strontium in the aquatic environment stays in the soluble state, which may be the reason for approximately the same concentrations of Sr^{90} in the organism of both predatory and carp fish (Table 1). Whereas Cs^{137} resides mainly in pseudocoloid form (60%) and only partially in soluble form - 10%.

It should also be noted that analysis of soil samples of S site, according to **Evseeva *et al.* (2012)**, showed high contamination of S territories to the level that some areas of the landfill can be qualified as radioactive waste (according to IAEA criteria). The reduction of radioactivity of the soil of the test site due to half-life of Co^{60}, Cs^{137}, Sr^{90}, Eu^{152}, Eu^{154} and accumulation-decay of Am^{241} will take at least 100 years, which leaves a real threat of contamination of the nearby territories and spread of radioactive elements due to natural phenomena as a result of atmospheric, underground and surface testing at the test site **(Yamamoto *et al.*, 2008; Evseeva *et al.*, 2012; Shahjahan *et al.*, 2022)**. Thus, examining soil samples at a distance of 60km from the landfill, **Yamamoto *et al.* (2008)** found the presence of both Cs^{137} and $Pu^{239,240}$ in the soil. Studies of contamination of surface soil spheres directly from the landfill by **Krivitskiy *et al.* (2022)** showed the presence of Am^{241} at doses from <0.3 to 390 Bq/kg and Cs^{137} - from <1.1 to 330 Bq/kg. **Aidarkhanov *et al.* (2013)** investigated contamination in the basin of the Shagan River, the only natural drain of the landfill. They recorded indicators of these elements (Am-241 and Cs-137) at levels of up to 30 Bq/kg (average) and highlighted the irregularity of contamination. Although the authors point out that there is no artificial migration of radionuclides with surface waters and that they cannot confirm the possible transboundary transfer of radioactive elements with the waters of the Shagan and Irtysh rivers, we have established the presence of radioactive elements in the hydrobionts of the Irtysh River. This finding correlates with the data of **Toropov (2018)**, who indicated that a large amount of radioisotope Sr^{90} migrates from the landfill with water flows (in soluble form - less than 3nm- as well as forming organic colloidal compounds).

Taking into account the long-term and intensity of soil contamination at the S site territory, monitoring of contamination of environmental objects of the adjacent territories (and the polygon as well), indication of radionuclide accumulation in organisms of domestic and wild animals remains an urgent task, as well as the study of peculiarities of

radioactive elements circulation in objects of animate and inanimate nature. The conducted research directed at the preserving and rational use of bioresources. It solves the food security problem, a part of which can be done due to the sustainable provision of fish products.

CONCLUSION

The content of Cs^{137} and Sr^{90} in the freshwater fish was tested during the conducted ecological monitoring in the Irtysh River. According to the obtained data, the content of tested elements was different at different sampling sites. Moreover, we have not found the dependence on the fish's feeding type and the radionuclide contents. Hence, Cs^{137} content was fixed at the levels from 0.43 Bq/kg (at the tributary of the Irtysh River, pikeperch) to 2.96 Bq/kg (Bukhtarma reservoir, roach). For Sr^{90}, the content level was fixed from 5.34Bq/kg (Irtysh channel, ruff) to 20.76Bq/kg (Irtysh tributary near Zevakino village, perch). Furthermore, the content of Sr^{90} was fixed at the higher levels in all fish samples compared to the Cs^{137}. This can be connected with the features of the radioactive elements to be soluble in the water environment that has its clear impact to transmission in the live organism's tissues.

Limitation

Sampling for the study was carried out in the period of April-August. Taking into account the obtained data, it is expedient to analyze the radioactivity of hydrobionts and water and mule samples in parallel at the sampling sites, taking into account the periods of drought and rainfall in the region.

Acknowledgment

The author is grateful to the specialists of the Republican Veterinary Laboratory of the State Inspection Committee of the Agricultural Complex of the Republic of Kazakhstan (Semey) for their help in conducting needed measures during our research conducting.

The research became a part of the specialized program "Comprehensive assessment of the ecological and epidemiological state of bioresources of the main fishery reservoirs of Kazakhstan for the formation of the state cadastre"; agreement with 'KazagroInnovation' No. 30-1 (25 February 2009). The research was granted by the Science Committee of the Ministry of Higher Education and Science of the Republic of Kazakhstan - grant no. AP19576259, 'Ecological assessment of small rivers as indicators of the transformation of geosystems in the mountainous regions of Eastern Kazakhstan'.

Conflict of interest

There is no conflict of interest.

REFERENCES

Aidarkhanov, A.O.; Lukashenko, S.N.; Lyakhova, O.N.; Subbotin, S.B.; Yakovenko, Y.Y.; Genova, S.V. and Aidarkhanova, A.K. (2013). Mechanisms for surface contamination of soils and bottom sediments in the Shagan River zone within former Semipalatinsk Nuclear Test Site. J. Environ. Radioact. 124: 163-170.

Aidarkhanova, A.; Larionova, N.; Tashekova, A.; Dyussembayeva, M.; Mamyrbayeva, A.; Timonova, L.; Shakenov, Ye.; Mulikova, A. and Aidarkhanov, A. (2024). Assessment of the radionuclide and chemical composition of the Irtysh River water at the Republic of Kazakhstan territory. RSC Advances. 14(36): 26208-26218.

Beisenova, A.S. (2020). Environmental problems in Kazakhstan. In: "Sustainable Development in Central Asia" Akiner, Sh., Hay, J., & Tideman, S. (Eds). Routledge, pp. 159-66 p.

Bratushkina, E.L.; Klymenkov, K.P. and Mekhova, O.S. (2018). Radiological examination of production. VSAVM, Minsk.

Evseeva, T.; Belykh, E.; Geras'kin, S. and Majstrenko, T. (2012). Estimation of radioactive contamination of soils from the "Balapan" and the "Experimental field" technical areas of the Semipalatinsk nuclear test site. J. Environ. Radioact. 109: 52-59.

Krasnoyarova, B.A.; Vinokurov, Yu.I. and Puzanov, A.V. (2020). Transboundary Irtysh: Features of National Water Use and International Cooperation. Pacific Geography. (1): 59-67.

Krivitskiy, P.Y.; Larionova, N.V.; Baklanova, Y.V.; Aidarkhanov, A.O. and Lukashenko, S.N. (2022). Characterisation of area radioactive contamination of near-surface soil at the Sary-Uzen site in the Semipalatinsk test site. J. Environ. Radioact. 249: 106893.

Kryshev, I.I.; Buryakova, A.A. and Sazykina, T.G. (2021)Assessment of Environmental and Economic Damage from Radioactive Environmental Pollution. Biol. Bull. Russ. Acad. Sci. 48(12): 2193-2200.

Kushkumbayev, S. and Mussabekova A. (2022). New Kazakhstan and the future of the organisation of Turkic States: key areas of cooperation. PERCEPTIONS: J. Intern. Affairs. 27(1): 74-90.

Lehun, A.L.; Mendes, A.B.; Takemoto, R.M. and Bueno Krawczyk, A.C.D.D. (2021). Genotoxic effects of urban pollution in the Iguaçu River on two fish populations. J. Environ. Sci. Health. Part A. 56(9): 984-991.

Lu, Y.; Yuan, J.; Du, D.; Sun, B. and Yi, X. (2021). Monitoring long-term ecological impacts from release of Fukushima radiation water into the ocean. Geogr. Sustain. 2(2): 95-98.

Mamilov, N.; Sharakhmetov, S.; Amirbekova, F.; Bekkozhayeva, D.; Sapargaliyeva, N.; Kegenova, G.; Tanybayeva, A. and Abilkasimov, K. (2021).

Past, current and future of fish diversity in the Alakol Lakes (Central Asia: Kazakhstan). Diversity. 14(1): 11.

Mettler, F.A. (2013). Essentials of Radiology. E-Book, Elsevier Health Sciences, 2013.

Minister of Health of the Republic of Kazakhstan. (15 Dec. 2020). On the approval of the sanitary rules 'Sanitary and epidemiological requirements for the protection of radiation safety'. KR DSM-76. Ministry of Justice of the Republic of Kazakhstan. (21822). URL: https://adilet.zan.kz/rus/docs/V2000021822

Minister of Health of the Republic of Kazakhstan. (2 Aug.2022). On approval of hygienic standards for ensuring radiation safety. Law of the Republic of Kazakhstan ҚР ДСМ-71. Accounting. Legislation. URL: https://zakon.uchet.kz/rus/docs/V2200029012

Monged, M.H.; Hassan, H.B. and El-Sayed, S.A. (2020). Spatial distribution and ecological risk assessment of natural radionuclides and trace elements in agricultural soils of northeastern Nile Valley, Egypt. Water Air Soil Pollut. 231(7): 338.

Osypova, N.I. (2004). Distribution of heavy metals in the organs and tissues of fish with different types of nutrition in the coastal-sorous zone of Baikal. Ecological safety in agriculture. Ref. J. (4): 805.

Rzabay, A.; Seriyev, B.; Beisov, E.; Kopbassarova, G. and Kurmanbayeva, D. (2022). Environmental and legal regulation of radioactive pollution management. JEMT. 13(3): 633-42.

Shah, Z.U. and Parveen, S. (2020). A review on pesticides pollution in aquatic ecosystem and probable adverse effects on fish. Pollut. Res. 39(2): 309-321.

Shahjahan, M.; Islam, M.J.; Hossain, M.T.; Mishu, M.A.; Hasan, J. and Brown, C. (2022). Blood biomarkers as diagnostic tools: An overview of climate-driven stress responses in fish. Sci. Total Environ. 843: 156910.

Toropov, A.S. (2017). Forms of cesium-137 presence in natural waters of the Semipalatinsk test site in model and full-scale experiments. Bul. Transbaikal State Univ. 23(12): 59-68.

Toropov, A.S. (2018). Study of forms of strontium-90 in natural waters using the example of the Semipalatinsk test site. Bull. Kuzbass State Tech. Univ. (2(126)): 12-21.

Witeska, M.; Kondera, E.; Ługowska K. and Bojarski B. (2022). Hematological methods in fish-Not only for beginners. Aquacult. 547: 737498.

Yamamoto, M.; Tomita, J.; Sakaguchi, A.; Imanaka, T.; Fukutani, S.; Endo, S.; Tanaka, K.; Hoshi, M.; Gusev, B.I. and Apsalikov, A.N. (2008). Spatial distribution of soil contamination by 137Cs and 239,240 Pu in the village of Dolon near the Semipalatinsk Nuclear Test Site: new information on traces of the radioactive plume from the 29 August 1949 nuclear test. Health Physics. 94(4): 328-337.