

Original Research

## Radionuclide Contamination of Fish in a Dammed Water Body of the Chernobyl Exclusion Zone: A Case Study of the Yanivskyi Backwater

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### Abstract

The results of the assessment of the levels of radionuclide contamination of fish in the dammed, conditionally impermeable Yanivskyi backwater of the Pripyat River in the Chernobyl Exclusion Zone (ChEZ) for the period 2008-2025 are presented. It was found that the activity concentration of radionuclides in representatives of the ichthyofauna of the backwater as of 2025 decreased compared to the beginning of our research of this water body in 2008, on average, by 1.6 times for the content of <sup>90</sup>Sr, and by 1.4 times for the content of <sup>137</sup>Cs (unlike closed water bodies such as lakes of the ChEZ, in which the activity concentration of <sup>137</sup>Cs in fish also decreases, and the activity concentration of <sup>90</sup>Sr - gradually increases). The activity concentration of radionuclides in fish from the studied water body exceeded the permissible levels (PL) for fish products adopted in Ukraine by 13-111 times for <sup>90</sup>Sr and 2-15 times for <sup>137</sup>Cs, with PLs of 35 and 150 Bq/kg, respectively. As of 2020-2025, the activity concentration of <sup>90</sup>Sr in the prey fish (non-predatory) species from the Yanivskyi backwater of the Pripyat River mainly exceeds the activity concentration of <sup>137</sup>Cs by 1.5-11.9



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times, and in predatory fish, this indicator was only 0.3-2.6. For comparison, we present data on radionuclide activity concentrations in representatives of the ichthyofauna from several water bodies of the ChEZ. The total radiation dose rate for fish from the Yanivskyi backwater was also estimated, which is within 2.0-8.7  $\mu\text{Gy/h}$ . The recorded levels of the average total absorbed dose rate for practically all studied fish of the Yanivskyi backwater exceed the screening dose of 2  $\mu\text{Gy/h}$  and are lower than the safe level of 10  $\mu\text{Gy/h}$  recommended within the framework of the European Commission's "PROTECT" project.

### Keywords

Chornobyl Exclusion Zone; activity concentration; Yanivskyi backwater of the Pripjat River; fish; radionuclides;  $^{137}\text{Cs}$ ;  $^{90}\text{Sr}$ ; water body; absorbed dose rate

## 1. Introduction

Radionuclides entering water bodies undergo various processes of distribution of substances between bottom sediments, water, and biological components of ecosystems, accumulating in aquatic organisms, particularly fish [1-11]. In water bodies that have been exposed to strong radionuclide impact as a result of the accident at the Chornobyl NPP and other man-made accidents at nuclear power plants, radionuclide accumulation in aquatic organisms can occur to very dangerous levels [12-23]. At the present stage, in the water bodies of the Chornobyl Exclusion Zone (ChEZ), the main dose-forming radionuclides for aquatic organisms are  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  [24-36]. In Ukraine, the State Hygienic Standards "Permissible Levels of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in Food and Drinking Water" were approved, in which the permissible specific activity of these radionuclides in fish was set at 35 and 150 Bq/kg, respectively [37].

The goal of our study was not only to analyze the levels of accumulation of long-lived radionuclides  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in fish of various species from a dammed (conditionally non-flowing) reservoir, which is now the Yanivskyi backwater (Yaniv backwater) of the Pripjat River, but also to calculate the radiation dose rate to fish in this reservoir. Assessment of the dose rate to fish is also an important component of comprehensive radioecological and radiobiological studies of water bodies subjected to intense radionuclide contamination. The final task of the work was to assess the levels of absorbed irradiation dose rate (AIDR) of radiation received by representatives of the most common fish species from the Yanivskyi backwater of the Pripjat River in the ChEZ due to external and internal sources of ionizing radiation in the pre-war period (as of 2020-2025).

## 2. Materials and Research Methods

The Yanivskyi backwater, separated from the main channel of the Pripjat River by an alluvial dam after the Chornobyl accident, can be divided into two sections: a deep-water (with depths of 6-14 m) lake-like stretch with a water surface area of 0.84  $\text{km}^2$  and a spur extending from it (with a width of up to 100 m and depths of no more than 6 m) with an area of 0.10  $\text{km}^2$ . Silty bottom sediments occupy an area of about 0.43  $\text{km}^2$ , sandy sediments - about 0.54  $\text{km}^2$ . The Yanivskyi backwater is located 2-3 km from the destroyed unit and in 1986, was one of the most radionuclide-contaminated water bodies in the ChEZ. During the construction of the Chornobyl

NPP and the city of Pripjat, the backwater was expanded and deepened to accommodate the river port of the of Pripjat. By the autumn of 1986, the Yanivskiy backwater, like other backwaters in the near ChEZ, was covered with a bulk dam to contain radioactive fallout that had entered its waters. The volume of water masses in the backwater is about 3.7 million m<sup>3</sup> with a water surface area of 0.94 km<sup>2</sup> [38].

The research was carried out mainly during the period 2020-2025 in the once-quite-contaminated-with-radionuclides Yanivskiy backwater of the Pripjat River, adjacent to the city of energy workers, Pripjat, which was evacuated in 1986. During the active phase of the Chornobyl accident, a large number of various ships and barges with cargo arrived at the city's pier, which is located on the shores of the Yanivskiy backwater. It was used to overcome the consequences of the accident. Port cargo cranes still stand on the shores of the bay. Rusted port cargo cranes still stand on the shores of the backwater. Fish for research were selected in accordance with the regulations for radioecological monitoring of water bodies and in cooperation with the State Specialized Enterprise "Ecocentre" of the State Exclusion Zone Management Agency of Ukraine.

In total, 10 fish species were studied – 4 predatory and 6 prey fish. Among the predatory fish, the following were analyzed: pike *Esox lucius* L. (3-5 years), European perch *Perca fluviatilis* L. (3-5 years), common zander or pikeperch *Sander lucioperca* L. (2-4 years), European catfish *Silurus glanis* L. (5-6 years). Among the prey fish species, phytophagous species were studied - common rudd or redeye *Scardinius erythrophthalmus* L. (3-9 years); zooplanktonophagous species - bleak *Alburnus alburnus* (3-5 years) and zope or blue bream *Ballerus ballerus* L. (3-6 years); benthophagous species - common bream *Abramis brama* L. (3-7 years), common tench *Tinca tinca* L. (3-7 years) and roach *Rutilus rutilus* L. (4-9 years). The classification of fish is based on the predominant feeding type for the indicated age groups, as described in [39, 40]. More than 250 fish specimens were analyzed. The average number of fish in the sample for each species was at least 10. The exceptions were representatives of such predatory fish species as European catfish and common zander, of which there were fewer than 10. Fish sampling was carried out three times a year, according to the "Ecocentre" regulations, during expeditions to the ChEZ by employees of the Institute of Hydrobiology of the NAS of Ukraine. Expeditions are planned, usually at the same time of departure - this is the end of April-beginning of May, August, and November. Therefore, seasonal fluctuations in activity concentration in fish, if any, could not affect the average annual values of activity concentration in fish of the water body.

Measurements of activity concentrations of <sup>137</sup>Cs in water, bottom sediments, and fish were performed based on a  $\gamma$ -spectrometric complex consisting of a GC4018-DET semiconductor coaxial detector; a Lynx digital spectrum analyzer, S502C GENIE-2000 basic software, and LS06067 lead shielding ("Mirion Technologies – Canberra", USA). Water samples were collected from a boat with a bathometer at the fish and sediment sampling sites. Depending on the water body, water samples were collected in 10-20 L sampling containers. The determination of <sup>90</sup>Sr activity concentrations was performed by radiochemical method using the oxalate method with measurement of the <sup>90</sup>Y daughter product using a low background setup (UMF-2000) [41]. Part of the samples was measured without a preliminary radiochemical procedure using a beta-radiation energy spectrometer (SEB-01-70, Ukraine). The values of the specific activity of radionuclides are given in the whole fish organism in Bq/kg mass at natural humidity. The measurement error was 10-25%. For the analysis of experimental values – obtaining standard deviations, average values, and correlation coefficients, the standard MS Excel set was used. The calculated standard

deviation fully characterized the sample variations according to [42, 43]. Depending on the bottom topography of the reservoir and the composition of bottom sediments in the places of fish catching, bottom sediments were collected in the amount of 1 to 3 samples using a device for selecting bottom sediments - bottom scoop SBS-100. In places where the bottom was homogeneous with the same depth along the net, 1 sample was collected in the central part. If the bottom sediments were heterogeneous (silted sand or silt), 2-3 samples were collected. In addition, bottom sediments were collected in shallow water, as well as in places where fish spawning was observed (in particular, egg laying on higher vegetation) and in pits. In the case of overlapping channels with different depths by nets, bottom sediments were collected at the edges of the net and in the center. Bottom sediment samples were taken, as a rule, from 0-35 cm well mixed.

The absorbed irradiation dose rate in fish was determined using a modified method described in [44, 45], based on software [46], using the features of seasonal migratory behavior of different fish species [39, 40].

### 3. Research Results and Their Discussion

The study of representatives of the ichthyofauna of the ChEZ water bodies poses certain difficulties. This is primarily due to the heterogeneity of radionuclide contamination in bottom sediments, which affects the diversity and differences in contamination of the fish organism itself. Often, in catches, when analyzing the activity concentration of radionuclides in fish caught in the same place in the reservoir and of the same size, it was observed that the activity concentration limits often differed greatly from each other. This, in our opinion, is related to the mosaic nature of radionuclide contamination of bottom sediments and ultimately fish food at a specific point on the bottom (vegetation that grows here, mollusks, benthic organisms, etc.). The activity concentrations across radionuclides in water and bottom sediments of various ecological zones of the studied Yanivskiy backwater are given in Table 1.

**Table 1** Average annual activity concentration of radionuclides in water (Bq/l) and ranges of activity concentration of radionuclides in bottom sediments (kBq/kg air-dry mass) of the Yanivskiy backwater (2018-2025).

Radionuclide	Water, Bq/l	Bottom sediments, coastal area (fish spawning), kBq/kg	Bottom sediments (feeding), kBq/kg	Bottom sediments (pits, wintering), kBq/kg
<sup>90</sup> Sr	8.4 ± 1.7	0.1-2.0	0.4-11.9	11.1-34.5
<sup>137</sup> Cs	0.9 ± 0.2	3.8-32.9	8.5-36.5	69.7-171.5

As our previous studies [25, 27, 38, 44, 45, 47-50] show, the highest radionuclide activity concentrations are characterized by fish from lakes located in the western and southwestern traces of the Chernobyl NPP accident emissions. For a visual comparison, we give Table 2 with the content of radionuclides in several representatives of the studied ChEZ water bodies, such as Vershyna Lake, Glyboke Lake, and the North-Western part of the Chernobyl NPP Cooling Pond (CP). The North-Western part, which became independent, is one of three water bodies that formed on the site of the former CP, after the water level dropped since 2014.

**Table 2** The activity concentration limit (minimum and maximum) values and average activity concentration of radionuclides (in brackets) in fish of the Yanivskiy backwater and some other water bodies of the ChEZ, Bq/kg of wet weight (2020-2025).

Fish, (M ± m, n-number of samples -specimens)	Radionuclide	
	<sup>90</sup> Sr	<sup>137</sup> Cs
<b>Yanivskiy backwater</b>		
Rudd, n = 45	1401-3900 (2533 ± 273)	286-2227 (450 ± 116)
Roach, n = 35	1084-2340 (1645 ± 251)	220-583 (365 ± 88)
Tench, n = 10	1450-1894 (1674 ± 222)	535-847 (690 ± 155)
Bream, n = 20	1125-1783 (1531 ± 234)	221-941 (339 ± 164)
Zope, n = 20	859-1380 (1160 ± 187)	528-941 (668 ± 171)
Bleak, n = 51	709-1210 (994 ± 105)	217-1160 (475 ± 117)
Perch, n = 35	500-1470 (938 ± 201)	520-2313 (1160 ± 288)
Pike, n = 20	564-1912 (640 ± 53)	483-1515(750 ± 184)
Zander, n = 8	462-877 (641 ± 174)	941-2175 (1849 ± 772)
Catfish, n = 5	759-1500 (1130 ± 371)	1060-1160 (1115 ± 51)
<b>Vershyna Like</b>		
Rudd, n = 25	105784-213300 (146194 ± 28259)	1738-5238 (3258 ± 881)
Prussian carp, n = 18	105859-139291 (125427 ± 14232)	984-2960 (1949 ± 527)
Perch, n = 10	36529-80915 (57384 ± 12887)	2884-5267 (4178 ± 833)
Pike, n = 15	36406-59860 (49976 ± 6022)	3635-6234 (4997 ± 815)
<b>Glyboke Like</b>		
Rudd, n = 25	17884-32700 (23740 ± 4895)	1698-4890 (2859 ± 708)
Roach, n = 25	13000-23600 (18659 ± 2092)	1189-4302 (2226 ± 407)
Prussian carp, n = 10	17000-18870 (17884 ± 785)	1415-1738 (1577 ± 162)
Perch, n = 25	7844-25300 (16460 ± 4614)	1320-7585 (4940 ± 1332)
Pike, n = 10	7240-13500 (11130 ± 1780)	2607-9640 (5259 ± 1341)
<b>North-western part of the Chornobyl NPP Cooling Pond</b>		
Rudd, n = 32	900-2500 (1455 ± 361)	402-1250 (840 ± 214)
Roach, n = 20	801-2040 (1441 ± 342)	253-784 (385 ± 92)
Prussian carp, n = 20	327-1210 (1059 ± 216)	505-1521 (859 ± 152)
Perch, n = 20	484-1110 (896 ± 141)	537-3223 (770 ± 187)

As can be seen from Table 2, representatives of the ichthyofauna of the Yanivskiy backwater at this stage have comparable levels of radionuclide contamination of <sup>90</sup>Sr and <sup>137</sup>Cs with fish from the CP and significantly lower radionuclide content than fish from Vershyna Lake and Glyboke Lake.

In general, for all studied representatives of the ichthyofauna of the Yanivskiy backwater of the Pripyat River, as of 2020-2025, the activity concentration of <sup>90</sup>Sr was within 462-3900 (1331 ± 383), and <sup>137</sup>Cs – 217-2313 (667 ± 184) Bq/kg. Thus, the activity concentration of <sup>90</sup>Sr and <sup>137</sup>Cs in prey fish was, respectively, 709-3900 (1659 ± 467) and 217-2227 (493 ± 121) Bq/kg, and for predatory fish, 462-1500 (787 ± 149) and 483-2313 (954 ± 205) Bq/kg, respectively.

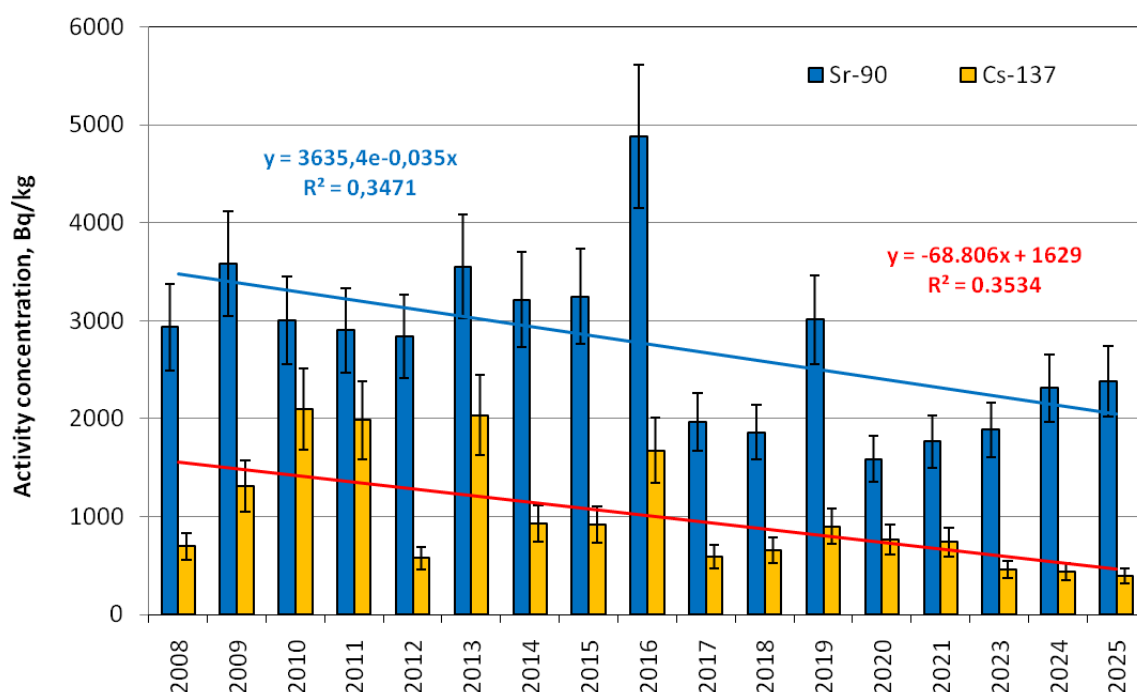
Among the studied fish species of the Yanivskiy backwater that have a high ability to accumulate <sup>90</sup>Sr and <sup>137</sup>Cs, it is worth noting the rudd, which is characterized by very high levels of

activity concentration of the radionuclides. The rather high levels of radionuclide accumulation in rudd are associated with plant food and, in particular, algae covered with phytoepiphyton, which are characterized by an extremely high ability to accumulate radionuclides [51].

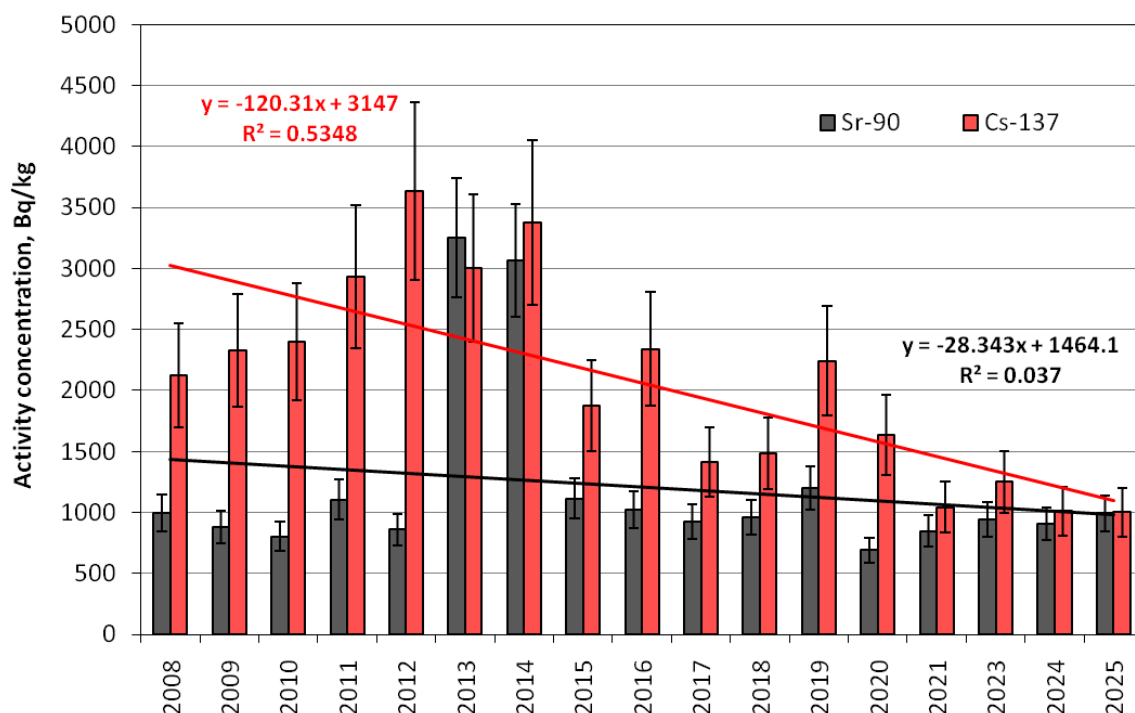
Predatory fish are traditionally considered to be the group that intensively accumulates <sup>137</sup>Cs. In the Yanivskiy backwater, they were represented mainly by perch and pike. High levels of <sup>137</sup>Cs accumulation in ichthyophagous fish are a well-known phenomenon in radioecology, which is associated with the effect of trophic levels in the assimilation of the radionuclide from the muscle tissues of prey fish species (which are mainly fed by predatory fish) and its increased accumulation in the body of predators. <sup>90</sup>Sr in fish is mainly found in tissues that are poorly digestible – bones and scales, head, and fins. Its accumulation by predatory species is less efficient than by “peaceful” species [25, 38, 44, 52].

The activity concentrations of radionuclides in fish of the Yanivskiy backwater in 2020-2025, in all cases, exceeded the permissible levels set by the standards adopted in Ukraine for fish products [37] – 13-111 times for <sup>90</sup>Sr and 2-15 times for <sup>137</sup>Cs.

Figure 1 and Figure 2 show the dynamics of the activity concentration of radionuclides in fish from the Yanivskiy backwater of the Pripyat River using the example of two fish species - rudd and perch, which dominated catches during 2008-2025 and are the most common in the water bodies of the ChEZ.



**Figure 1** Dynamics of the average annual activity concentrations of radionuclides and their linear approximation for the prey (non-predatory) fish from the Yanivskiy backwater using the example of the rudd (2008-2025).



**Figure 2** Dynamics of the average annual activity concentrations of radionuclides and their linear approximation for the predatory fish of the Yanivskyi backwater using the example of the perch (2008-2025).

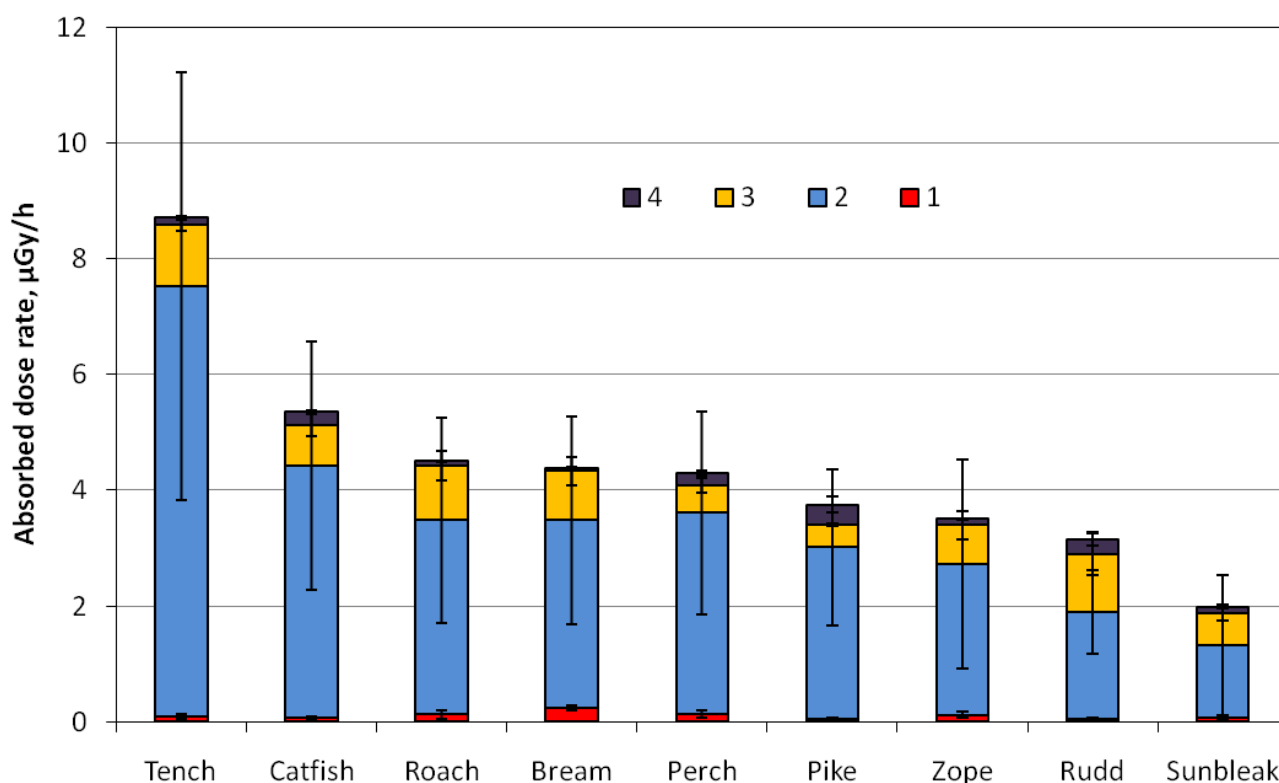
Analysis of the data obtained for the studied period shows that the activity concentration of  $^{137}\text{Cs}$  in all representatives of the ichthyofauna from the Yanivskyi backwater continues to decrease with certain fluctuations, as shown in Figure 1 and Figure 2 using the example of rudd and perch. The content of  $^{90}\text{Sr}$  in representatives of different species of fish in this water body decreases rather smoothly or, practically, remains at the same level, with certain deviations in both directions. This is primarily due to the increase in the activity concentration of  $^{90}\text{Sr}$  in groundwater of the surrounding areas, and accordingly in the water of the Yaniv backwater, which has been observed more noticeably for the lakes of the left bank floodplain of the Pripjat River (Vershyna Lake, Glyboke Lake, etc.) and Azbuchyn Lake (located on the right bank of the Pripjat River) since the late 1990s [27, 38, 48]. Subsequently, such jumps in the  $^{90}\text{Sr}$  content were recorded in terrestrial plants and hydrobionts – higher aquatic plants, mollusks, and fish [24, 25, 35, 36, 49]. But, if in closed water bodies such as Azbuchyn Lake, Vershyna Lake, or Glyboke Lake, the activity concentration of  $^{90}\text{Sr}$  increases in fish, then there is probably a certain outflow of this radionuclide with the water masses through the embankment dam that separates the backwater from the Pripjat River. In connection with which, we classified the Yanivskyi backwater to a conditionally non-flowing water body.

The fish of the studied water body differ significantly not only in the total specific activity of radionuclides, but also in their ratio in the body of various representatives of the ichthyofauna. As of 2020-2025, the activity concentration of  $^{90}\text{Sr}$  in prey fish of the Yanivskyi backwater exceeds the activity concentration of  $^{137}\text{Cs}$  by 1.5-11.9 times, and in predatory fish, this indicator is 0.3-2.6.

Thus, the activity concentration of radionuclide  $^{137}\text{Cs}$  in predatory fish of the studied backwater, in the vast majority of cases, exceeds the activity concentration of  $^{90}\text{Sr}$  in their body. Prey fish accumulate  $^{90}\text{Sr}$  more effectively, whereas predatory (ichthyophagous) fish accumulate higher

levels of  $^{137}\text{Cs}$ . This is because the radionuclide  $^{137}\text{Cs}$  is mainly found in the muscle tissues of fish, which the predator feeds on, and is absorbed by the predator's body. At the same time,  $^{90}\text{Sr}$  is mainly concentrated in inedible calcium-containing organs and tissues (scales, bones, head, fins) that transit through the body of the ichthyophagous organism.

Therefore, knowing the activity concentrations in the abiotic components of the ecosystem of a water body and the activity concentration of radionuclides in fish, it is possible to calculate the dose rate experienced by representatives of the ichthyofauna of water bodies and the consequences associated with it [28, 29, 44]. According to our calculations, the average total radiation dose rate to the body of various fish species in 2021 ranged from 2.0 to 8.7  $\mu\text{Gy}/\text{h}$ . The highest absorbed dose rate was recorded in bottom-dwelling fish species, as shown in Figure 3. And the smallest is in the pelagic bleak.



**Figure 3** Average annual absorbed dose rate in 2021 to the fish species from the Yanivskyi backwater: 1 - external dose rate due to  $^{90}\text{Sr}$ ; 2 - external dose rate due to  $^{137}\text{Cs}$ ; 3 - internal dose rate due to  $^{90}\text{Sr}$ ; 4 - internal dose rate due to  $^{137}\text{Cs}$ .

As is known, the total dose rate to fish consists of the dose from external radiation exposure (from radionuclides in the shores of the water body, bottom sediments and water column) and the dose received from internal sources of radiation, i.e. from radionuclides incorporated into fish (internal radiation dose).

In general, the absorbed dose rate of radiation to fish in the studied reservoir from external sources depends on the radionuclide  $^{137}\text{Cs}$  by 94-99%. While the absorbed radiation dose rate to fish from radionuclides incorporated into fish (internal radiation dose) is 58-93% due to  $^{90}\text{Sr}$ . Figure 3 also shows that the total radiation dose to representatives of various ichthyofauna species in the Yanivskyi backwater is 58-85% due to the absorbed dose received by fish from

irradiation with  $^{137}\text{Cs}$ . Basically, this is the fraction received by fish due to external exposure to  $^{137}\text{Cs}$  from radionuclide contamination of the bottom sediments, shores, water, etc. (because the fraction of internal absorbed dose from incorporated  $^{137}\text{Cs}$  is generally negligible, as shown in Figure 3).

For fish in this water body, the total dose rate consists of 59-87% from external exposure and only 13-41% from the internal absorbed dose of exposure from radionuclides incorporated into the body. Our research also showed that the total absorbed dose rate (external and internal) received by the fish of the Yanivskyi backwater in 2025 from  $^{90}\text{Sr}$  exposure was only 12-37%. It should be noted that the role of  $^{90}\text{Sr}$  in the formation of the total radiation dose to fish is significantly higher for closed water bodies - lakes of the left-bank floodplain of the Pripjat River and the right-bank Azbuchyn Lake [25, 45, 50].

Thus, the recorded levels of the average annual absorbed dose rate for practically all studied fish of the Yanivskyi backwater exceed the screening dose of  $2\ \mu\text{Gy}/\text{h}$  and are lower than the safe level of  $10\ \mu\text{Gy}/\text{h}$  recommended within the framework of the European Commission's "PROTECT" Project [53, 54].

#### 4. Conclusions

Based on our research on the ichthyofauna of the conditionally impermeable, dammed Yanivskyi backwater of the Pripjat River, the following has been established:

1. The activity concentration of  $^{90}\text{Sr}$  in representatives of the ichthyofauna of the Yanivskyi backwater was within the range of 0.46-3.90 kBq/kg, and  $^{137}\text{Cs}$  – 0.22-2.31 kBq/kg. The activity concentration of radionuclides in fish from the water body during the research period often exceeded the permissible levels, according to the standards adopted in Ukraine for fish products – 13-111 (on average 39) times for  $^{90}\text{Sr}$  and 2-15 (on average 4) times for  $^{137}\text{Cs}$ .

2. The activity concentration of  $^{90}\text{Sr}$  in prey ("peaceful") fish species of the Yanivskyi backwater was on average 2.0 times higher than in predatory fish (except for the pelagic bleak). At the same time,  $^{137}\text{Cs}$  was, on average, 2.8 times lower. The activity concentration of  $^{90}\text{Sr}$  in prey fish species as of 2021-2025 was in the range of 0.71-3.90, and in predatory fish, within 0.46-1.50 kBq/kg, while the activity concentration of  $^{137}\text{Cs}$  in prey and predatory fish species was, respectively, 0.22-2.23 and 0.48-2.31 kBq/kg. As of 2020-2025, the activity concentration of  $^{90}\text{Sr}$  in prey fish species of the Yanivskyi backwater exceeds the activity concentration of  $^{137}\text{Cs}$  by 1.5-11.9 times, and in predatory fish, this indicator is 0.3-2.6. Among the studied fish of the water body, the highest activity concentration of  $^{90}\text{Sr}$  was noted in the rudd.

3. The activity concentration of  $^{137}\text{Cs}$  in fish of the studied water body during the research period continued to decrease naturally with fluctuations within the limits of variation for different samples. The  $^{90}\text{Sr}$  activity concentration in representatives of the ichthyofauna of this water body remained at a practically constant level or showed a barely noticeable tendency to decrease.

4. The average total absorbed dose rate to various fish species in the studied water body as of 2020-2021 was within the range of 2.0-8.7  $\mu\text{Gy}/\text{h}$ . The share of the total dose rate from exposure to only  $^{137}\text{Cs}$  received by fish from the Yanivskyi backwater is more than half of the total dose to fish with radionuclide exposure, namely 58-85%. It arose mainly from external exposure to fish (via radionuclides in bottom sediments, water, shores, etc.). Although the main contribution of  $^{137}\text{Cs}$  to the fish's entire body may be due to external irradiation, the internal dose to individual

organs, such as bones, spinal cord, and brain, is significantly higher and is caused by  $^{90}\text{Sr}$  (which accumulates most in calcium-containing organs and tissues of fish - the head, spine, bones, and scales).

5. The calculated levels of the average annual absorbed dose rate for practically all studied fish from the Yanivskiy backwater exceed the screening dose of  $2 \mu\text{Gy/h}$ , but do not exceed the safe level of  $10 \mu\text{Gy/h}$ , recommended within the framework of the European Commission's "PROTECT" Project and some other documents [53, 54] (unlike the lakes, which are also located in the 10 km ChEZ).

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### Author Contributions

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### Competing Interests

The authors have declared that no competing interests exist.

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