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ORIGINAL ARTICLE

Accumulation of radionuclides in Dnipro reservoir fish

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In this work the questions concerning the influence of pollutants on the water bioresources of the Dnipro (Zaporizhzhia) reservoir are considered. The results of researches of fish pollution in the Dnipro (Zaporizhzhia) reservoir concerning natural and artificial radionuclides are presented. The general β-activity is determined, the levels of accumulation of natural and artificial radionuclides by hydrobionts are established. The limits of their distribution between organs and in the body of individual fish species, depending on the type of food they eat, are given. The results of general β-activity in fish organs, depending on their type of food, are presented. The conducted studies of the content of radioactive contamination of hydrobionts in the reservoirs indicate that the increase in the content of radionuclides in the body depends on the type of food and the intensity of migration of radionuclides.

The determined indicators of the status of aquatic organisms allow to establish the fish response to increased radioactive contamination, provide an opportunity to estimate the levels of accumulation of radionuclides in the organism of fish and their distribution in organs.

Keywords: Water bioresources; hydrobionts; pollutants; types of nutrition; Dnipro (Zaporizhzhia) reservoir; cesium-137; strontium-90; migration of radionuclides

Introduction

At present the problem of distribution and accumulation of different origin pollutants in the natural systems is urgent (Anisa et al., 2014; Yarovyi et al., 2017), it greatly affects the biological indices of fish in the Dnipro areas with different levels of industrial loading (Kotovska et al., 2015). Excessive anthropogenic pressure on natural reservoirs causes a significant deterioration of the existence conditions of not only rare, but also mass species of fish (Ananyeva et al., 2016; 2018). Natural and synthetic compounds are introduced into marine and river waters, it is an integral part of technology-related urban and agro-industrial human activities in all countries around the world (Antonenko et al., 1978; Garcia-Sanchez, 2008; Novitskii et al., 2011). Under the influence of pollution there is a transition to a definite end condition, which to a certain extent does not depend on the initial ecological diversity of the groups (Potapenko et al., 2017).

Migration and accumulation of artificial origin radionuclides are much more active in the central streambed of the Dnipro River than in its subordinate river systems, in particular, it concerns the reservoirs of Ukraine affected by the Chernobyl accident (Bilokon et al., 2014).

During the Chernobyl accident the Dnipro and its confluents became the main receivers of surface runoff, which washed away radionuclides not only from the 30-kilometer ChNPP zone but also from the entire catchment area of the river, which actively migrate with food chains and accumulate in the fish bodies as the last link in the food chain (Bulakhov et al., 2008).

According to Sapronova V.O. (2017) the content of cesium-137 in the fish of the Dnipro (Zaporizhzhia) reservoir does not exceed 150 Bq kg^{-1}, but the constant intake it by a person can contribute to the gradual accumulation of radionuclide in the human body and endanger the health of the population. In the modern faunal complex of the Dnipro (Zaporizhzhia) Reservoir Vertebrates Fish (*Pisces*) are represented by a class of Bony Fish (*Osteichthyes*), an underclass of Actinopterygians (*Actinopterygii*), which include 13 orders. Today, in the ichthyofauna reservoir there are 57 species of fish (15 families) (Novitskyi, 2016).

23 species are cultivated, 3 species (eastern bream, European carp, European pike perch) belong to valuable industrial species, and two species to the category of low-value industrial fish. The basis for the fishery is roach (up to 41.0%), benthophages (41.6%-88.0%) dominated in industrial catching by trophicity of feeding, plankton eaters are smaller group (10.0-44.0%), and biomass of predators in catches is negligible (4.7-29.6%). In natural ecosystems representatives of the

ichthyofauna constitute the final links of the trophic chains, which largely determines the direction of radionuclides migration in the ecosystems of reservoirs directly to the human body (Novitskyi, 2016).
The problem of studying the accumulation of artificial radionuclides as well as radionuclides of natural origin in water by hydrobionts is considered through monitoring studies during which the level of migration of radionuclides in certain fish species in the waters of Dnipro (Zaporizhzhia) reservoir was studied, during which the level of radionuclides migration in certain species of fish in the water areas of the Zaporizhzhia reservoir was determined (Bilokon et all, 2014) on the example of roach (Ananieva, 2016), as well as the influence of a powerful industrial pressure on biological parameters, especially the accumulation of radionuclides by the white carp in Dnipro (Zaporizhzhia) reservoir (Ananiyeva, 2018).
According to the literary data the accumulation of radionuclides with fish occurs individually for each species. Young fish more actively accumulate strontium than mature individuals (Volkova, 1990; 2010). This is due to the fact that the growing organisms require more calcium to build the skeleton than adults and strontium accumulates with calcium (Dvoreckii,1990; Kaglian, 2000).
The aim of this work was to study the peculiarities of the distribution of radionuclides in the organism of certain species of fish in the Dnipro (Zaporizhzhia) reservoir in the autumn of 2018.

Methods

Fish samples were taken in the autumn of 2018 in the upper section of the Dnipro (Zaporizhzhia) reservoir (the place where the Mokra Sura falls into) from fishermen-amateurs and with using a grid. There were selected samples of 10 units of carps, 7 units of pike-perches, 23 units of crucian carps, 8 units of silver carps, 7 units of white bream, 10 units of roaches, 3 units of eastern bream. According to the method samples of 2 kg of raw mass were taken, they were dried at t + 105 ° C in a drying box and then subjected to ignition according to generally accepted methods (Koblitskaya, 1981), statistical processing was carried out (Gerfort, 1984). The activity of radionuclides in the organism of fish was measured using a gamma-ray scintillation spectrometer СЕГ-001 "АКР-С" and a beta-ray spectrometer СЕБ-01-150 expressed in Becquerel per kilogram (Bq kg^{-1}) of raw, natural weight. The process of radionuclides accumulation was evaluated using a coefficient of accumulation (concentration coefficient), which was calculated as the ratio of the radionuclides concentration in the sample to the concentration of radionuclides in water. Digital data was mathematically processed by general methods of variation statistics using the Microsoft Excel 2016.

Research results and their discussion

Studies have established that in the study period the overall β-activity in investigated species of fish ranged from 58.08 in the carp organism to 138.84 in eastern bream. The content of cesium-137 ranged from 0.12 Bq kg^{-1} in crucian carp to 15.1 Bq kg^{-1} in eastern bream. The amount of strontium-90 varied from 0.24 Bq kg^{-1} in roach and crucian carp to 37.5 Bq kg^{-1} in the silver carp body (Table 1).

Table 1. Levels of radioactive contamination of fish in the Dnipro (Zaporizhzhia) reservoir (Bq kg^{-1}, M ± m)

Species	Total ß-activity	^{137}Cs	^{90}Sr
Roach (*Rutilus rutilus*)	79.05 ± 2.66	0.39 ± 0.05	0.24 ± 0.02
Eastern bream (*Abramis brama)*	138.84 ± 4.20	15.10 ± 6.50	1.70 ± 0.27
White bream (*Blicca bjoerkna)*	92.62 ± 3.60	2.54 ± 0.63	8.30 ± 1.20
Silver carp (*Hypophthalmichthys molitrix*)	101.22 ± 2.72	0.20 ± 0.01	37.50 ± 4.11
Carp (*Cyprinus carpio)*	58.08 ± 2.03	0.48 ± 0.12	0.60 ± 0.27
Pike-perch *(Sander lucioperca*)	110.20 ± 6.10	5.22 ± 1.40	2.80 ± 0.23
Crusian carp (*Carassius gibelio)*	66.60 ± 1.20	0.12 ± 0.02	0.24 ± 0.01

When investigating the amount of radionuclides in fish organs it becomes evident that the most active in the content of cesium-137 is a mixture of organs of eastern bream and pike-perch as well as muscles of white bream. The smallest amount of this kind of radionuclide is contained in the muscle of silver carp. The most amount of strontium-90 is in bones of eastern bream and white bream, and less extent is in the muscles of the crucian carp and the silver carp. As for the distribution of potassium-40 its scale ranged from 0.89 Bq kg^{-1} in the muscles of the crucian carp to 77.4 Bq kg^{-1} in the bones of the eastern bream (Table 2).

Table 2. Indices of radionuclide contamination of ^{137}Cs and ^{90}Sr in fish of the Dnipro (Zaporizhzhia) reservoir, Bq kg^{-1}.

Species	^{137}Cs	K-40	^{90}Sr
Eastern bream			
Bones	<0.59	186.80	77.40
Muscles	<1.79	116.50	1.64
Mix	<5.82	124.60	5.78
White carp			
Bones	<0.13	96.50	40.52
Muscles	<0.01	108.60	0.94
Mix	<0.20	98.60	5.75
Pike-perch			
Bones	<1.15	106.80	10.45
Mix	<5.75	105.60	1.89
White bream			
Muscles	<7.44	128.50	2.49
Bones	<0.17	122.70	64.05
Crucian carp			
Muscles	<0.38	77.30	<0.89
Bones	<0.40	8.50	<21.30
Mix	<0.05	95.70	2.93

The studies of the content of total β-activity in fish organs have shown that the indices are determined in the bones (171.88-363.13 Bq kg^{-1}) in muscle (122.49-252.43 Bq kg^{-1}). By type of feed the total β-activity is characteristic for bentophages, which are fed with molluscs and other representatives of benthos. In bentophages' bones total β-activity was 588.82 Bq kg^{-1}; the lowest values of total β-activity are noted in phytoplanktophages (white carp)-336.83 Bq/kg, which is also related to the type of feed (Table 3).

Table 3. Total β-activity in fish organs, depending on the type of feed, (Bq kg^{-1})

Types of food	Total β-activity		
	Bones	**Muscles**	**Total**
Carnivorous	363.13	165.2	528.33
Phytoplanktophages	214.34	122.49	336.83
Zooplanktophages	171.88	215.49	387
Bentophages	336.39	252.34	588.82

The accumulation coefficients of ^{137}Cs in the fish of the Dnipro reservoir were in the range from 35.0 to 1424, ^{90}Sr - from 74 to 1426 (Table 4).

Table 4. Average indicators of radionuclide accumulation coefficients in fish of the Dnipro (Zaporizhzhia) reservoir

Species	Level of radionuclide accumulation	
	^{137}Cs	^{90}Sr
Roach	260-1138	321-1206
	70	830
Eastern bream	294-1409	327-1424
	894	891.7
Pike-perch	214-1140	98-143
	780	120.5
White bream	35-78	34-96
	56.5	65
Carp	35.0-67.5	46-74
	52.25	60
Crusian carp	97-112	74-95
	104.5	89
White carp	197-210	35-74
	203.5	54.5

Note. Above the line min-max values; under the line – average.

The content of radionuclides in the organisms of the investigated species indicates that eastern bream is more vulnerable to the Cs-137 and Sr-90 content: it has the highest levels of accumulation both elements. The pike-perch and the silver carp actively accumulate radionuclides of cesium-137 and react less to the supply of strontium-90. On the contrary the roach contains strontium-90 ten times more than cesium-137. Crucian carps, white bream and perch are the most neutral in relation to radionuclides of artificial origin (Figure 1).

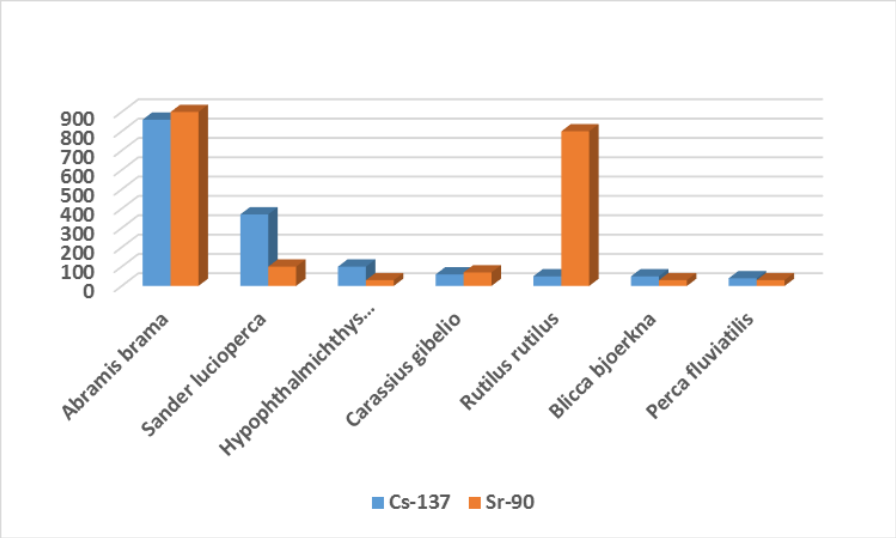

Figure 1. Coefficients of accumulation of 137Cs and 90Sr in the fish of the Dnipro (Zaporizhzhia) reservoir.

Conclusion

It was established that in the water of the Dnipro (Zaporizhzhia) reservoir the process of migration of natural and artificial radionuclides is continuing, which affects the state of water bioresources. The maximum levels are β-activity and accumulation of Cs^{137}, the maximum amount of Sr^{90} accumulate in the bones and internal organs of the eastern bream A. brama.

It is determined for the first time that the distribution of radionuclides is influenced by the type of fish feed in the water. The most neutral to accumulation of this listing of pollutants among the studied species was crucian carp: the minimum indices of β-activity, the amount of cesium-137 radionuclides, strontium-90 and potassium-40.

The determined indices of radionuclide contamination of fish make it possible to establish a fish response to increasing of radioactive contamination, provide an opportunity to estimate the levels of accumulation of radionuclides in the organism of fish and their distribution in organs.

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