The Environmental Safety of Fish Products

N V Popova¹, A I Pavlova²

¹Associate Professor of the Department of Physiology of Farm Animals and Ecology of the Faculty of Veterinary Medicine, Arctic GATU, Yakutsk, Russia
²Professor of the Department of Physiology of Farm Animals and Ecology, Faculty of Veterinary Medicine, Arctic State Technical University, Yakutsk, Russia

E-mail: erel.popova@mail.ru, Pavlova_ai2018@mail.ru

Abstract. The anthropogenic pollution of the environment leads to the discharge of various pollutants into water ecosystems, which further accumulate in fish and other hydrobionts. Fish is a valuable traditional food source for humans, and the quality assessment for fish products is therefore a relevant problem. This article deals with researching the content of pollutants in game fish, in particular in the Siberian whitefish. The goal of this work is to identify the content of heavy metals and cesium 137 in the muscle tissue and organs of the fish (whitefish) caught in the lower reaches of the Lena River. Research methods: The sampled materials were tested for heavy metals using the atomic absorption method. The content of Cs 137 was established using the spectrometric method. Results: the average concentration values for heavy metals (mg/kg) (Pb, Cd, Hg) in the muscle tissue and organs of the whitefish do not exceed the limits. The average content of lead in muscular tissue is 0.0135±0.0025 mg/kg, cadmium - 0.0076±0.0014 mg/kg, and mercury 0.0011±0.0000 ug. Arsenic was not found in the muscle tissue and organs of the fish. The highest relative content of heavy metals was observed in the livers of the whitefish. The content of cesium 137 is insignificant and below the allowed level of radionuclide activity. Conclusion: The analysis of the research results shows that the contents of heavy metals and cesium 137 in the fish caught in the lower reaches of the Lena do not exceed the standard levels. The on-going pollution of lakes and rivers within the Lena watershed calls for regular monitoring of heavy metal and radionuclide content and accumulation in game fish.

1. Introduction
The anthropogenic impact has been increasing over recent decades, and environmental pollution is a problem everywhere. Industrial development leads to the deterioration of the environment in the arctic regions of Yakutia. The pollution of lakes and rivers with wastes from mines, utility companies, water, and land transport leads to negative consequences. According to environmental monitoring data, the quality of the surface waters is rated as ‘moderately polluted’ and ‘polluted’ [6]. The contamination of freshwater reservoirs leads to the significant reduction of commercial stocks of game fish. Fish is a key component of water ecosystems. Moreover, game fish used as food is one of the key sources of proteins, easily digested fats, vitamins, macro- and microelements. The fishery has a huge significance for the people of the north, and it is a key area of their economic activities. These people have been fishing for ages: in the late XIX century, at least 11 thousand tons of fish were caught in the waterways of Yakutia (F. N. Kirillov, 1972). The highest capture level in the water bodies of Yakutia was
observed in the 1940es. In the following years, these levels decreased and stabilized at an average of 7 thousand tons [11, 14].

Currently, the pollution of waters makes especially relevant the quality assessment of raw fish and fish products in terms of environmental safety, i.e. the content of various pollutants.

The works of various authors feature the data on the content of heavy metals and radionuclides in fish caught in different regions that illustrate water pollution (Taylor D., 1983; Sorensen, 1992; Eichenberger, E., 1993; Kashulin, et al., 1999; Glazunova, 2003; Gomboyeva, 2003; Klenkin, et al., 2008; Wei Y., et al., 2014; Popov, Androsova, 2014; Zubkova et al., 2016; Trapeznikov, et al., 2019). According to I. Ya. Vasilenko (1999), radioactive cesium stands out among other anthropogenic radionuclides that pollute the biosphere all over the world because small amounts of this element can be found almost everywhere. The emission of radioactive cesium into the environment mainly happens as a result of nuclear weapon tests and accidents at nuclear power plants.

Despite the extensive study of the water and game fish pollution in other regions, the data on the level of heavy metals and radionuclides in fish and the environmental safety of fish as food for the people of Yakutia are scarce.

2. Research goal and objective
The goal of this work is to evaluate the adequacy and quality of fish products. When assessing the quality of fish products, it is important to take into account both the content of nutrients and the results of physical, chemical, and biological tests. The objectives of our research included the identification of toxic metal content in fish muscle and organs, as well as the radionuclides in the muscular tissue of the fish.

3. Research materials and methods
This work was carried out at the Department of Livestock Physiology and Ecology of the Arctic State Agrotechnological University and the Yakutian Republican Veterinary Testing Laboratory. The study material comprised the Siberian whitefish, Coregonus sardinella (Valenciennes) caught during autumn and winter. The material was harvested in the lower reaches of the river Lena in Zhiganskiy and Bulunskiy districts of the Republic of Sakha (Yakutia). The content of toxic metals (Pb, Cd, Hg, As) in the muscular tissue and organs of the Siberian whitefish was determined by the nuclear absorption spectrometric method used with the Spektr-5 analyzer. The content of toxic elements (Pb, Cd, Hg, As) in the muscle tissue of the fish was evaluated according to Sanitary Regulations and Norms 2.3.2.1078-01.

The accumulation of cesium 137 in the muscular tissue of the whitefish was measured using the radionuclide activity metering method with a scintillation gamma-ray spectrometer and the Progress software.

4. Results
The whitefish is one of the key game fish species in the lower and middle reaches of Yakutian rivers during the spawning migration and this fish has long been used as food by the people of the North. The study of the chemical content and caloric value of the filets and bellies of the Siberian whitefish showed that the whitefish is a product with medium content of protein, and an extra fatty fish according to the content of the fat in the bellies. Besides, this fish contains vitamins, macro- and microelements, and all the essential amino acids (A. A. Gnedov, 2010; A. F. Abramov, et al., 2015).
The influence of anthropogenic factors on river ecosystems over the last fifty years led to the reduction of valuable game fish stocks, including the whitefish. Thus, according to L. N. Sivtseva and N. V. Popova (2009), while the gross catch of the whitefish in the fishery basins of Yakutia was over 5 thousand tons a year in 1943, the yearly average catch over the recent decades is on average 750 tons (Figure 1). Currently, the stocks of valuable game fish, including the whitefish, in the rivers of the republic are undermined by irrational fishing (harvesting small immature whitefish in the feeding spots) [9,11].

The biology of the whitefish inhabiting the rivers of Yakutia is described by a number of authors (F. N. Kirillov, 1972; A. F. Kirillov, 2010; B. I. Sidorov, 2004; A. F. Kirillov, L. N. Sivtseva, F. N. Zhirkov, et al., 2010). The literature describes the whitefish as a medium-sized fish of up to 40 cm long and weighing over 1 kg in Yakutia. The normal length of mature adults is between 25 and 35 cm, while the normal weight is 120-400 g. The ceiling age in Yakutia is 12 years. The whitefish spends most of its life in the desalinated coastal waters and near river deltas. In different waterways and during different seasons the whitefish feeds on different things. In Lena, especially in its lower delta, its diet mostly consists of plankton and river-dwelling invertebrates, such as caddis worms, stoneflies, copepods, and cladocerans, as well as Cyanophyta during summers (June to September). In winter, larger fish feed on mysids, bottom dwellers, young fish, and fish eggs.

The spawning run has two discernible peaks: the first one is in July and August, which concurs the omul run, and the second in the last third of September and October, which ends at the beginning of winter under ice. The spawning grounds are located in low-current rivers and sandy courses. The average individual absolute fecundity is 11,456 eggs. The average length of the whitefish in the reproductive guild over the last 25 years is 281 mm [14].

During the spawning run, the whitefish eats small amounts of caddis worms, stoneflies, and cladocerans. The migrating whitefish has a lot of fat that covers the entire alimentary tract in a thick layer as well as a significant accumulation of intermuscular fat in the back and belly parts, which allows the fish to stop eating during the spawning migration [14,22].

We know that aquatic organisms, including fish, are depressed in water bodies that are polluted with toxic substances. Their numbers dwindle, and reproductive processes break down [17].

The results of laboratory tests for the content of some heavy metals and cesium 137 in the muscles of the Siberian whitefish are presented in Table 1. The data on the presence of toxic metals and radionuclides in fish are required to check whether some toxic elements are accumulated in the organs and tissues of the fish and to evaluate the adequacy and environmental safety of the fish as food.
Table 1. The content of toxic metals and cesium 137 in the muscular tissue of the Siberian whitefish.

| Indicators    | Toxic metal content, mg/kg, M±m | Permissible levels in mg/kg, max |
|---------------|---------------------------------|---------------------------------|
| Lead (Pb)     | 0.0135±0.0025                   | 1.0                             |
| Cadmium (Cd)  | 0.0076±0.0014                   | 0.2                             |
| Mercury (Hg)  | 0.0011±0.0000                   | 0.5                             |
| Arsenium (As) | Not found                       | 5.0                             |
| Caesium 137   | 1.2275±4.4923                   | 130.0                           |

Table 1 shows that the content of heavy metals in muscles is insignificant and well below the LOC for heavy metals in food materials and products. The average content of lead (LOC 1.0 mg/kg) in whitefish muscles is 0.013 mg/kg, cadmium – 0.007 mg/kg (LOC 0.2 mg/l), mercury – 0.001 mg/kg (LOC 0.3 mg/kg). Lead and cadmium are the dominant pollutants.

The results also show that there is some cesium 137 in whitefish muscles. Its specific activity on average is 1.2275±4.4923 Bq/kg, which corresponds with the low level of accumulation. The literature features data on the accumulation of radionuclides in fish inhabiting the water bodies located in the areas contaminated with radionuclides. Predatory fish like the pike, perch, and catfish have the highest content of cesium 137 (A. V. Shashko, L. N. Shashko, 2009). There is also some data concerning the sea game fish: the isotopes of cesium can be found in seafood caught in the Japanese coastal waters [30].

The result comparison showed that the liver and the gills of the whitefish contain more lead and cadmium than its muscles (Figure 2). The content of lead in the liver was 2.6 times higher and 1.9 times higher in the gills than in the muscles. The content of cadmium was 4.4 and 1.8 times higher respectively.

The highest content of toxic metals was observed in the livers of the whitefish. Thus, the content of lead in the whitefish liver is decreasing along the following sequence: Pb > Cd > Hg.

The analysis of the information on the content and accumulation of heavy metals in Coregonidae from various water bodies of Yakutia shows that the content of the metals in questions in the organs and the tissues of the fish was low. According to N. V. Popova and L. N. Markova (2013), all of the inspected organs and muscles of the omul contain iron as the most prominent element, zinc and copper share the second place, and the amounts of lead, cadmium, and mercury are very small. The average content of lead in the meat of the game omul in the lower reaches of the river Lena is 0.230±0.002 mg/kg, while the same value for the Indigirka population is almost four times higher – 0.952±0.001 mg/kg. A relatively high (although below the LOC) content of lead was observed in the fish from the river Kolyma – 0.838±0.002 mg/kg. We found out that the content of heavy metals in the fillets and bellies of the whitefish was insignificant. The average content of lead in fillets was 0.15±0.003 mg/kg (Lena), 1.022±0.001 mg/kg (Indigirka); the content of mercury was 0.020±0.001 (Lena) and 0.108±0.001 (Indigirka) (A. F. Abramov, et al. 2018; N. V. Popova, A. F. Abramov, 2019).
A number of works mention the accumulation of zinc, copper, lead, cobalt, and mercury in the organs of ordinary fish caught in the areas exposed to industrial and urban impacts within the Vilyui watershed and the middle reaches of the Lena (D. D. Savvinov A. F., et al. 1993; A. N. Nyukkanov, 2004; Kirillov, V. V. Khodulov, 2006; A. F. Kirillov, et al., 2009).

5. Findings
The distribution of toxic metals in the muscle tissue and organs of the whitefish is uneven. We established that the content of toxic metals in muscles and organs of the whitefish is low and within the requirements of the Sanitary Regulations and Norms. The highest content of these metals was observed in the livers and the gills of the whitefish, which may be connected to the consumption of the metals along with the feed, the metabolic and depot function of the liver, and the pickup of elements from water.

The content of cesium 137 in the fish is within the acceptable levels. Its average value is 1.2275±4.4923 Bq/kg.

6. Conclusion
We established that the content of toxic metals, such as lead, cadmium, and mercury in the muscular tissues and organs of the Siberian whitefish is low and within the requirements of the Sanitary Regulations and Norms. The highest relative content of heavy metals was observed in the livers of the fish.

The laboratory tests showed that the content of cesium 137 is low and within the acceptable levels. The presence of heavy metals and cesium 137 in the muscles and organs can be attributed to the environmental situation in the region, the anthropogenic pollution of lakes and rivers within the Lena watershed, and the accumulation of heavy metals within the environmental chain.

7. References
[1] Abramov A F 2015 Nutritional and biological value of Siberian vendace (Coregonus sardinella valenciennes) of the Sakha Republic (Yakutia) Yakutsk Medical Journal 3 pp 87-89
[2] Abramov A F 2018 Food and biological value of freshwater fish of the rivers of Yakutia (Novosibirsk: Ed. ANS "SibAK") 154 p
[3] Vasilenko I Ya 1999 Radioactive cesium 137 Nature 3 pp 70-76
[4] Glazunova I A 2003 The content and features of the distribution of heavy metals in the organs and tissues of fish from the upper Ob Izvestia of the Altai State University 3(29) pp 93-95
[5] Gnedov A A 2010 Siberian vendace (Coregonus sardinella (Valenciennes)) - quality indicators, nutritional value (Science and modernity) 4-1 pp 370 - 375
[6] Gomboeva S V 2003 Ecological features of the distribution of heavy metals in fish of the Baikal region: Dis. ... Candidate of Biological Sciences (Ulan-Ude) 130 p
[7] State report on the state and protection of the natural environment of the Republic of Sakha (Yakutia) an annual publication [Electronic resource] https://minpriroda.sakha.gov.ru/gosdoklady-o-sostojanii-okruzhajuschej-sredy (date of access: 30.04.2020)
[8] Zubkova V M, Rozumnaya L A, Bolotov V P 2016 The content of heavy metals in tissues and organs of different fish species of the Volgograd reservoir Bulletin of the Astrakhan State Technical University. Series: Fisheries 4 pp 93-98
[9] Karpova L N 2015 Results of monitoring of aquatic biological resources on water bodies of the Republic of Sakha (Yakutia) Bulletin of Fisheries Science Vol 2(6) pp 3-17
[10] Kashulina N A 1999 Fish of fresh waters of the Subarctic as bioindicators of technogenic pollution (Apatity: RAS) 142 p
[11] Kirillov F N 1972 Fish of Yakutia (Moscow: Nauka) 360 p
[12] Kirillov A F, Khodulov V V 2006 Assessment of the impact of the mining industry on the fish fauna of inland water bodies Bulletin of KBSU. Series "Biological Sciences". - Nalchik: Cab. - Bulk. University Issue 8 pp 69-72
[13] Kirillov A F, Khodulov V V, Mamilov N Sh 2009 Ichthyofauna of the Lena River under the conditions of increasing anthropogenic load Biodiversity and sustainable development of nature and society: Materials of the international scientific and practical conference (Kazakh National University named after Al-Farabi, May 12-13, 2009) (Alma-Ata: Kazak University) Part 2 pp 92-94
[14] Kirillov A F, Sivtseva L N, Zhirkov F N and others 2010 Fish fauna of the lower reaches of the Lena River on the territory of Zhiganskij region (Yakutsk: Dani Almas Company) 75 p
[15] Klenkin A A 2008 Heavy metals in commercial fish of the Azov Sea Fishing issues Vol 9 2(34) pp 503-512
[16] Nyukkanov A N 2004 The impact of natural toxicants on aquatic organisms of the Republic of Sakha (Yakutia): author. dis. ... Dr. Biol. Sciences; 03.00.16 (Krasnoyarsk) 30 p
[17] Popov P A 2002 Assessment of the ecological state of water bodies by methods of ichthyoin dication (Novosibirsk) 270 p
[18] Popova N V 2008 Comprehensive assessment of water pollution in the Lower Lena and the quality of fish products Agrarian Bulletin of the Urals 1(43) pp 65-66
[19] Popova N V 2013 Heavy metals in muscle tissue and organs of commercial fish Women and modern challenges: collection of articles. articles of scientific and practical. conf. (Yakutsk) pp 231-234
[20] Popova N V, Abramov A F 2019 Environmental safety and nutritional value of commercial whitefish in Yakutia (Bulletin of IrGSKhA) 93 pp 86 - 94
[21] Popov A S, Androsova N V 2014 The content of heavy metals in the muscle tissue of fish from reservoirs of the Ob river basin Bulletin of the Tomsk State University. Biology 4(28) pp 108 - 122
[22] Sivtseva L N, Popova N V 2009 Fishing in the Lower Lena and the content of heavy metals in the muscle tissue of Siberian vendace Materials of the scientific-practical conference "Agrarian education: scientific works of youth - agriculture" (Yakutsk) pp 102-104
[23] Sidorov B I 2004 Freshwater fishes, amphibians and reptiles of Yakutia: Reference guide (Yakutsk: Bichik) 64 p
[24] Trapeznikov A V 2019 Basic principles for assessing the safety of fish products from water bodies exposed to the effects of nuclear fuel cycle enterprises Medical-biological and sociopsychological problems in emergency situations I pp 106-114

[25] Shashko A V, Shashko L N 2009 Accumulation and content of cesium-137 in the body of fish inhabiting the water bodies of the Pripyat Polesie (Pinsk: PolesGU) 2 pp 14-18 https://rep.polessu.by/handle/123456789/7687

[26] Eichenberger E 1993 The relationship between the need and toxicity of metals in the aquatic ecosystem Some questions of the toxicity of metal ions (M.: Mir) pp 62 - 87

[27] Savvinov D D, Tyaptirgyanov M M, Krivoshapkin V G et al 1993 Ecology of the Vilyui River: the state of the natural environment and health of the population (Yakutsk: YaNTs SO RAN) 140 p

[28] Sorensen E M 1992 Metal poisoning in fish U.S.A. Texas CRC Press 363 p

[29] Taylor D 1983 The significance of the accumulation of cadmium by aquatic organisms pp 211-235

[30] Wei Y, Zhang J, Zhang G, Tu T, Luo L 2014 Metal concentrations in various fish organs of different fish species from Poyang Lake, China Ecotoxicology and environmental safety 104 pp 182-188

[31] Information on the Great East Japan Earthquake http: // www.mhlw.go.jp/english/topics/2011eq/index.html