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Ecological and hygienic evaluation of the accumulation and distribution of cadmium compounds in organs and tissues of Yakutia freshwater fish

ABSTRACT

The paper analyzes the results of the accumulation of heavy metals – particularly cadmium in the organs and tissues of freshwater fish in the waters of Yakutia, which is one link in the food chain "water-fish-man." According to the toxicology cadmium is considered to be one of the most dangerous to human health ecotoxicants. There are very little data on the cadmium content in the organism of Yakutia freshwater fish. Meanwhile, these data are not only of theoretical but also of practical importance, since the toxicity of cadmium is independent from the form of its compounds, as one can observe in the case of lead and mercury compounds, "soluble" metal chemical forms (i.e., those which pass through a filter with a pore size of 0.45 microns) are equally toxic. Our studies have shown that the highest level of cadmium was found in the liver of large perch in the summer period with age from 4 + to 6 + years, caught in the river Vilyuy and had 0.411 ± 0.290 mg / kg of cadmium in the body wet weight. This amount exceeds 2.1 times the Maximum Permissible Level. Apparently, because of the change of feeding in the winter period, in small immature species some trend towards reduction of cadmium in the liver was observed.

It should be noted that the main commercial product is a muscle tissue of the studied fish from different water reservoirs of Yakutia, which at present have no particular risk to human health because cadmium in muscle tissue is present in amounts not exceeding the maximum allowable levels.

Keywords: human health, heavy metals, cadmium, toxic element, age groups, trend.

It is known that cadmium is one of the most dangerous ecotoxicants and is close to mercury and arsenic by toxicity [6, 7].

In nature, cadmium is not found in the free form and does not form special ores. Cadmium is produced commercially as a by-product of zinc and copper refining (Marcus, 1991). In the middle-aged humans there is about 50 mg of cadmium, 1/3 concentrates in kidneys, the remaining amount in the liver, lungs and pancreas. With age, the content of cadmium in the body increases, in the newborn cadmium is absent and it occurs at10 months of life.

Daily intake of cadmium by the adult is about 215 micrograms. Cadmium is not an essential element for mammals [19].

Nonetheless, epidemiological data suggest cadmium's extreme danger to humans. Due to the fact that this element is very slowly eliminated from the human body (0.1% per day), cadmium poisoning may turn into chronic form. Its symptoms are the damage to kidneys, nervous system, lungs, sexual dysfunction, and joint pain. There is credible evidence of carcinogenic risk of cadmium. Today it is estimated that in about 5% of the population of the United States and Japan, the concentration of cadmium in the body has reached a critical level.

According to the Austria Institute of Food data no mercury or lead, namely cadmium is the most dangerous heavy metal.

The global annual intake of cadmium from natural sources is about 8.43 x 10-5 kg (Table. 1) [17]. This is the result of plants vital activity, soil, dispersed by wind, volcanic aerosols and forest fires. Annual emission into the atmosphere as a result of the activities of the industry is estimated to be 7.19 x 10^5 kg. Atmospheric depositions effectively remove cadmium from the atmosphere. Therefore, the concentration of cadmium in rainwater may exceed 50 mg / l [18].

In the river uncontaminated and slightly contaminated waters cadmium is contained in submicrogram concentrations, in contaminated and waste water cadmium concentration can reach tens of micrograms per 1 dm^3 [4]. Cadmium rapidly migrates into acidic and soft water, as free ions and soluble compounds. Therefore, preferential presence in forms available to aquatic organisms is typical for cadmium [3].

The intensity of cadmium anthropogenic emission on the water surface reaches 132 tons per year [11]. Natural background concentrations of cadmium are generally less than 1 mg / l [10].

It was established that embryos of aquatic organisms are most susceptible to toxic effects of cadmium. Studies on minnows, and then on other fish species have shown teratogenic effects of cadmium compounds, demonstrated in a variety of spinal deformities. Behavioral effects of cadmium were also observed [10].

Toxic effects of cadmium on fish are not fully understood. It is known that cadmium accumulates mainly in the gills, liver and kidneys. However, the impact of the detected amounts of cadmium on the functioning of these organs is unclear, although there is some evidence that it is involved in osmoregulatory processes in the gills and kidneys. Cadmium is slowly cleared from the tissues of fish after transfer from the contaminated water to clean one, at the same time the accumulation occurs rapidly and causes death of organisms within a few days [1, 5, 8, 9]. All heavy metals, including cadmium, contained in the soil through natural propagation can be used for monitoring, as well as be the basis of forward-looking information relating to the pollution in the water column organisms [2]. The high content of heavy metals (cadmium, mercury, lead and other) in Rivers Tom, Ob', in the city of Novosibirsk, in the upper zone of the Bratsk reservoir in some rivers of Yakutia was reliably detected by chemical methods. It was also confirmed by the fact of increased, and in some cases, high levels of these elements in fish in these reservoirs [13, 14, 15, 16].

There is very little data on the content of cadmium in the body of Yakutia freshwater fish. Meanwhile, this data is not only of theoretical but also of practical importance, since the toxicity of cadmium is independent from the form of its compounds, as one can observe in the case of lead and mercury compounds, "soluble" metal chemical forms (i.e., those which pass through a filter with a pore size of 0.45 microns) are equally toxic[14].

Our studies have shown that the highest level of cadmium was found in the liver of large perch in the summer period with age from 4 + to 6 + years, from the river Vilyuy and was 0.411 ± 0.290 mg / kg of cadmium in the organ green weight. This amount exceeds the MPL 2.1 times. In the liver of perch, in the same population, caught in winter, cadmium content was almost the same – 0.399 ± 0.282 mg / kg. In the same population of perch, but small species under the age of 2 + years, in summer cadmium's concentration in the liver was 0.165 mg / kg and in the winter time - 0.079 mg / kg of the organ green weight. Apparently, because of the change of feeding in the winter period, in small immature species some trend towards reduction of cadmium in the liver was observed.

Cadmium is distributed in tissues and organs in the perch from the river Vilyuy in the following order: liver – gills – muscle – gut - bone.

On this basis, it can be assumed that the main "gateway" of cadmium emission to perch organism is gills.

In guppies (Poecilia reticulata), which during 7 weeks ate worms - pipe makers (Tubifex), containing 20 mg / kg cadmium, showed no accumulation of toxic element [1]. In another group of fish, kept within that period in the water, contained 70-100 mg Cd / l, accumulated about 9 mg of Cd / kg (on the green weight) and, within this group there was no difference between the fish, which were fed with clean and cadmium-containing worms [1].

This again suggests the idea that the intake of cadmium compounds by fish is carried out through the gills, which is confirmed by the results of field trials (Table. 2).

Cadmium content in muscle tissue of perch from the river Vilyuy was within the MPL, and this fish is relatively safe when used for food. It is necessary to draw attention to the fact that the individuals in this group identified a significant excess of the MPLs in muscle tissue, which is 0.411 mg / kg (Table. 2). For this reason, one needs to expose the study of adult perch from the river Vilyuy and to prevent the use in food fish products containing cadmium above the MPL.

Based on these data, cadmium does not accumulate in the gut of perch. In the investigated fish we couldn't release intestines from the content because of the methodological difficulties of this operation. In the intestine of small perch specimens under the age of 2 + years small amount of cadmium contains. Thus, in summer their amounts are 0.095 mg / kg, in winter - 0.036 mg / kg; in large species in the summer - 0.118 mg / kg, in the winter - 0.116 mg / kg. As can be seen from the data, there are no significant differences in the content of cadmium in perch in different periods of the year.

Weis P. (1988) [20] considers that the process of elimination of the compounds of cadmium and mercury from the body goes through the intestines of fish. In our studies in Amginskiy area (p. Amga) fish (Table. 3) MPL exceeding of cadmium were not detected.

In muscle tissue of pike from the river Chroma (Table. 4) only in adult species cadmium was equal to 0.285 mg / kg in the summer and 0.164 mg / kg in the winter, which is close to the MPL. In the liver of the same pike MPL was much larger and composed in the summer 0.454 mg / kg, in the winter - 0.462 mg / kg, which exceeds the value 1.5 - 1.6 times. In the gills of adult fish in the summer it was 0.313 mg / kg, which exceeds the MPL 1.04 times.

In chir populations of the river Chroma only in the liver of adult fish exceeding MPLs in winter equal to 0.375 mg / kg were found, which exceeds the MPL value 1.6 times.

In perch from the Kolyma River (Table. 5) cadmium was in much smaller quantities in organs and tissues in comparison with the perch from the river Vilyuy. For example, if in the summer in large perch species of the river Vilyuy liver contained 0.411 mg / kg (Table. 2), then the fish population of the Kolyma river cadmium concentration was 0.251 mg / kg, in Indigirka population in large species in the liver was only 0.229 mg / kg of cadmium (Table. 6), i.e., the amount that may be within the maximum permissible level for freshwater fish.

Distribution of cadmium in the organs and tissues of the Kolyma, Indigirka perch populations (Table. 5, 6) is the same as in Vilui population (Table. 2). Perch in the rivers of the Kolyma and Indigirka, like other species of freshwater fish, showed a slight decrease of cadmium in the winter season.

In the body of the Verkhnekolymsky district carp cadmium levels were somewhat higher compared to Vilyui district carp. Thus, in large species aged 4 + to 6 + years old, caught in the summer in the lake Ozhogino (Verkhnekolymskiy district), the muscle tissue contained 0.108 mg / kg Cd, while the population of carp from the lake Dengkyude Vilyui district - 0.097 mg / kg. In the same situation were lake Dargalah Moma district, muscle tissue contained 0.093 mg / kg Cd, while the population of carp from the lake Ebe Vilyui district - 0.083 mg / kg. But these differences were not statistically significant because of the large error average.

These concentrations can be considered as the background content of cadmium in the body of the Yakutia lake carp, as these lakes are not subject to any local or any other human impact due to the remoteness from major population centers and the lack of flood waters from other polluted aquatic environments.

According to the degree of cadmium accumulation organs and tissues of Verkhnevilyuisk district carp are located in the following order: liver – gills – muscle – bone - intestine.

In roach from the River Vilyuy cadmium (Table. 2) is in the organs and tissues within the maximum permissible levels for freshwater fish. However, some large specimens established exceeding MPLs in the liver during the summer, reaching up to 0.3 mg / kg.

In Chukuchan fish Kolyma River Srednekolymsky region (Table. 5) the content of cadmium in the organs and tissues was within the maximum permissible levels for freshwater fish.

These data show that most of cadmium accumulates in adult perches, especially in the liver and gills (Table. 2-6). On this basis, one should limit the consumption of liver of perch 5 + - 7 + years of age, and possibly from younger species, and only after the toxicological studies.

Thus, in the literature data there is very little information about the content of cadmium in the body of Yakutia freshwater fish. Meanwhile, the field studies data carried out by us are not only of theoretical but also of practical importance, since the toxicity of cadmium is independent from the form of its compounds. Excess of cadmium in Yakutia freshwater fish is 1-2 MPC, often in polluted water, more often localizing in the gills and liver of the fish.

It should be noted that the main commercial product is a muscle tissue of the studied fish from different water reservoirs of Yakutia, which at present has no particular risk to human health because cadmium in muscle tissue is present in amounts not exceeding the maximum allowable levels.

No doubt, contaminated fish also affect human health. Thus, Yakutia freshwater fish must be intensively studied as a model for ecotoxicological research.

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Table 1

Isolation of cadmium from natural sources (thousand tons per year)

Natural source	Values range	Mean value
Soil particles carried by the wind	0.01 – 0.04	0.21
Sea salt aerosols	0 – 0.11	0.06
Volcanoes	0.14 – 1.5	0.82
Forest fires	0 – 0.22	0.11
Continental biogenic particles	0 - 0.83	0.15
Continental biogenic volatile substances	0 – 0.8	0.04
Marine biogenic sources	0 – 0.1	0.05
Total emission	0.15 – 2.6	1.3

Table 2

Accumulation and distribution of cadmium in the organs and tissues of Viliuisk district freshwater fish

Study period	Age of fish	Muscles	Liver	Intestine	Gills	Skeleton
Pike (*Esox lucius*)						
Summer	Up to 2+	0.006±0.004	0.061±0.043	0,007±0,005	0,031±0,022	0,048±0,034
	From 4+ up to 6+	0,015±0,011	0,032±0,0023	0,021±0,015	0,126±0,089	0,057±0,040
Winter	Up to 2+	0,004±0,003	0,041±0,029	0,003±0,002	0,017±0,012	0,031±0,022
	from 4+ up to 6+	0,009±0,006	0,038±0,027	0,027±0,019	0,103±0,073	0,112±0,079
Roach (*Rutilus rutilus*)						
Summer	Up to 2+	0,096±0,068	0,102±0,072	0,081±0,057	0,107±0,076	0,083±0,059
	from 4+ up to 6+	0,178±0,0126	0,189±0,134	0,125±0,088	0,141±0,100	0,131±0,093
Winter	Up to 2+	0,062±0,044	0,097±0,068	0,039±0,028	0,094±0,066	0,051±0,036
	from 4+ up to 6+	0,091±0,064	0,172±0,123	0,078±0,055	0,144±0,102	0,096±0,068
Perch (*Perca fluviatilus*)						
Summer	Up to 2+	0,111±0,078	0,165±0,117	0,095±0,067	0,127±0,090	0,091±0,064
	from 4+ up to 6+	0,162±0,114	0,411±0,290	0,118±0,083	0,316±0,223	0,107±0,076
Winter	Up to 2+	0,052±0,037	0,079±0,056	0,036±0,025	0,072±0,051	0,062±0,044
	from 4+ up to 6+	0,094±0,066	0,399±0,282	0,116±0,082	0,215±0,152	0,131±0,093

Table 3

Accumulation and distribution of cadmium in the organs and tissues of Amginskij district freshwater fish

Study period	Age of fish	Muscles	Liver	Intestine	Gills	Skeleton
Pike (*Esox lucius*)						
Summer	Up to 2+	<0,01	0,012±0,008	<0,01	<0,01	0,012±0,008
	From 4+ up to 6+	<0,01	0,014±0,010	<0,01	<0,01	0,013±0,009
Winter	Up to 2+	<0,01	0,010±0,007	<0,01	<0,01	0,010±0,007
	from 4+ up to 6+	<0,01	0,011±0,008	<0,01	<0,01	0,011±0,008
Roach (*Rutilis rutilus*)						
Summer	Up to 2+	<0,01	0,019±0,013	<0,01	<0,01	<0,01
	from 4+ up to 6+	<0,01	0,016±0,011	<0,01	<0,01	0,013±0,009
Winter	Up to 2+	<0,01	<0,01	<0,01	<0,01	<0,01
	from 4+ up to 6+	<0,01	0,011±0,008	<0,01	<0,01	0,012±0,008
Perch (*Perca fluviatilis*)						
Summer	Up to 2+	<0,01	0,013±0,009	<0,01	<0,01	0,012±0,008
	from 4+ up to 6+	<0,01	0,015±0,011	<0,01	<0,01	0,013±0,009
Winter	Up to 2+	<0,01	0,011±0,008	<0,01	<0,01	0,011±0,008
	from 4+ up to 6+	<0,01	0,013±0,009	<0,01	<0,01	0,011±0,008

Table 4

Accumulation and distribution of cadmium in the organs and tissues of pike and chir in the reservoir of Chroma River (Allaihovskij district, August – October 2006, n = 10)

Study period	Age of fish	Muscles	Liver	Intestine	Gills	Skeleton
Pike (*Esox lucius*)						
Summer	Up to 2+	0,170±0,120	0,209±0,148	0,095±0,067	0,199±0,141	0,081±0,057
	From 4+ up to 6+	0,285±0,201	0,454±0,321	0,137±0,097	0,313±0,221	0,097±0,068
Winter	Up to 2+	0,097±0,068	0,108±0,076	0,044±0,031	0,137±0,097	0,047±0,033
	from 4+ up to 6+	0,164±0,116	0,462±0,326	0,082±0,058	0,284±0,201	0,132±0,093
Chir (*Coregonus nasus*)						
Summer	Up to 2+	0,094±0,070	0,102±0,072	0,096±0,068	0,114±0,081	0,113±0,080
	from 6+ up to 8+	0,241±0,170	0,298±0,211	0,231±0,163	0,201±0,142	0,163±0,115
Winter	Up to 2+	0,074±0,052	0,123±0,087	0,062±0,044	0,102±0,072	0,063±0,044
	from 6+ up to 8+	0,128±0,090	0,375±0,265	0,116±0,082	0,237±0,167	0,137±0,097

Table 5

Accumulation and distribution of cadmium in the organs and tissues of Srednekolymskij district freshwater fish

Study period	Age of fish	Muscles	Liver	Intestine	Gills	Skeleton
Dace (*Leuciscus leuciscus*)						
Summer	Up to 2+	0,082±0,058	0,116±0,082	0,051±0,036	0,095±0,067	0,081±0,057
	From 4+ up to 6+	0,104±0,073	0,146±0,103	0,073±0,052	0,104±0,073	0,093±0,066
Winter	Up to 2+	0,053±0,037	0,083±0,066	0,027±0,019	0,072±0,051	0,063±0,044
	From 4+ up to 6+	0,089±0,063	0,107±0,076	0,053±0,037	0,081±0,057	0,079±0,056
Chukuchan (*Catostomus catostomus*)						
Summer	Up to 3+	0,081±0,057	0,092±0,065	0,089±0,063	0,088±0,062	0,061±0,043
	from 6+ up to 8+	0,127±0,090	0,197±0,139	0,092±0,065	0,129±0,092	0,123±0,087
Winter	Up to 3+	0,073±0,052	0,094±0,066	0,058±0,041	0,072±0,051	0,064±0,045
	from 6+ up to 8+	0,089±0,063	0,167±0,118	0,053±0,037	0,116±0,082	0,097±0,068
Perch (*Perca fluviatilis*)						
Summer	Up to 2+	0,131±0,093	0,157±0,111	0,092±0,065	0,031±0,022	0,082±0,058
	From 4+ up to 6+	0,256±0,181	0,251±0,177	0,201±0,142	0,199±0,141	0,112±0,079
Winter	Up to 2+	0,093±0,066	0,106±0,075	0,046±0,032	0,091±0,064	0,087±0,061
	From 4+ up to 6+	0,122±0,086	0,203±0,143	0,059±0,042	0,121±0,085	0,065±0,046

Table 6

Accumulation and distribution of cadmium in the organs and tissues of Allaihovskij district freshwater fish

Study period	Age of fish	Muscles	Liver	Intestine	Gills	Skeleton
Pike (*Esox lucius*)						
Summer	Up to 2+	0,143±0,101	0,156±0,110	0,103±0,073	0,034±0,024	0,066±0,047
	From 4+ up to 6+	0,302±0,213	0,323±0,222	0,198±0,140	0,207±0,146	0,126±0,089
Winter	Up to 2+	0,089±0,063	0,187±0,134	0,054±0,038	0,091±0,064	0,080±0,056
	From 4+ up to 6+	0,243±0,172	0,288±0,203	0,057±0,040	0,097±0,068	0,063±0,044
Dace (*Leuciscus leuciscus*)						
Summer	Up to 2+	0,063±0,044	0,087±0,061	0,051±0,036	0,073±0,052	0,069±0,049
	From 4+ up to 6+	0,102±0,072	0,143±0,101	0,089±0,063	0,121±0,085	0,094±0,070
Winter	Up to 2+	0,056±0,040	0,089±0,063	0,041±0,029	0,079±0,056	0,064±0,045
	From 4+ up to 6+	0,086±0,061	0,116±0,082	0,062±0,044	0,095±0,067	0,087±0,061
Perch (*Perca fluviatilus*)						
Summer	Up to 2+	0,132±0,093	0,151±0,107	0,091±0,064	0,046±0,036	0,071±0,050
	From 4+ up to 6+	0,208±0,147	0,229±0,162	0,186±0,131	0,267±0,189	0,131±0,093
Winter	Up to 2+	0,091±0,064	0,102±0,072	0,063±0,044	0,093±0,066	0,097±0,068
	From 4+ up to 6+	0,149±0,105	0,208±0,147	0,067±0,047	0,165±0,117	0,102±0,072