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Content of Cd, Cu, Cr, Fe Mn, Ni and Pb in Water and Selected Organs of Blotched Picarel *Spicara maena* L. and Mezgit *Merlangius euxmus* L. from Karantinna Bay and Balaklava Bay in the Region of Sevastopol

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1. Introduction

Accumulation of trace elements in water organisms is an important problem related to contamination of the environment and their use for food purposes (Zhong et al., 2018). Due to a specificity of biogeochemical circulation of trace elements, we often observe their increased amounts in water reservoirs. Chemical elements emitted to atmosphere together with gas and dust contaminations in consequence of dry and wet deposition fall into the surface of water reservoirs or land from where they are washed away (Sikora et al., 2018). In water reservoirs most of elements precipitates in the form of soluble salts or because of absorption and adsorption processes, they link to bottom deposits. Bottom deposits constitute an integral part of water ecosystems. Organic matter decomposition and accumulation of mineral and organic compounds introduced to reservoirs from the area of drainage basin, takes place. Raised amounts of trace elements of organic contaminations in bottom deposits are often observed, even in the conditions of their low concentration in water (Qiu et al. 2011). Those deposits are also a place of living for many water organisms, which constitute an alimentary base for higher animals, including fish. Heavy metals accumulated in fish bodies are collected together with food or directly from water through gills or skin. The increased content of trace elements in water organisms results in numerous negative changes at the level of a population, biocenose or the entire ecosystem. At the level of a population, embryotoxic and mutagenetic impact is observed, which induces problems related to the reduction of the reproductive success of water organisms and mutations leading to degeneration of particular specimens (Kong et al., 2013). Heavy metals influence reduction of the amount of spawn, disorders of movement of sperm cells leading to the limitation of fertilization, death of embryos and reduce the survival rate of larvae (Arambourou et al., 2014). Seaside ecosystems are more exposed to negative effects of environmental pollution due to a considerable impact of land to shaping of their ecosystem. Particularly sensitive are estuaries where considerable amounts of pollution brought with river waters, and bays, with city centres (Van Praet et al., 2014; Ordog et al., 2004). Estuarine and bay areas are significant from the point of view of obtaining food. A great amount of organic matter and nutrients introduced to the sea from land, low depths of reservoirs and higher temperatures cause that the seaside has an enormous potential of primary production. It is also a place of living and reproduction of many species of fish. Due to closeness of densely populated areas and a considerable production potential, on estuarine areas and shallow bays often aquaculture units are located. Fish, seafood obtained from the area with a raised level of antropopression often have an increased content of trace elements even in the conditions of their low content in particular elements of the marine ecosystem (Boalt et al., 2014, Bonsignore et al., 2018). Monitoring of the trace elements content in water organisms enables, on one hand assessment of a threat for consumers and on the other hand, determination of the level of contamination of the ecosystem in the context of biocenose impact (Niemiec et al., 2016). Assessment of the trace elements content in biotype elements such as water of bottom deposits does not allow for a full evaluation of the condition of the environment since the content of trace elements does not translate into the level of accumulation in living organisms which is emphasised by many authors (Kong et al., 2013, Niemiec et al., 2015, Niemiec et al., 2018a). Except for the total content of elements in environment, their collection by living organisms is influenced by the conditions and properties of environment such as salinity and water reaction and content of organic matter as well as content of other elements which may synergistically or antagonistically influence the collection of elements. The level of bioaccumulation of trace elements also depends on the species of an organism, its age, physiological condition, and properties related to the individual variability. Monitoring of the environment of marine ecosystems is incredibly significant from the point of view of planning and evaluation (Jia et al., 2018). Due to great volumes of salty water reservoirs, their variable depth and considerable territorial differences in xenobiotic accumulation, monitoring is very difficult and obtaining credible results leading to appropriate conclusions must be preceded with a suitable approach to collection of samples for their chemical analysis and correct interpretation of results (Van Praet et al., 2014). One of the most dangerous effects of contamination with heavy metals is reduction of the reproductive success of fish through mutagenic and embryotoxic potency (Kong et al., 2013). Heavy metals influence reduction of the amount of spawn, disorders of movement of sperm cells leading to limitation of fertilization, death of embryos and reduce the survival rate of larvae (Arambourou et al., 2014).

The goal of the study was to evaluate a content of Cd, Cu, Cr Ni, Fe, Mn and Pb content in water and in selected organs (gills, tissue, gonads, and liver) blotched picarel *Smaris smaris* L. and mezgit *Merlangius euxmus* L. from Krarantinna and Balaklava Bay in the region of Sevastopol. The second aim was to determine the level of bioaccumulation of those elements in organisms used in the studies.

2. Material and methods

Studies were carried out in 2017 in two bays of Sevastopol: Balaklava and Karantinna. Samples of water were collected from the surface layer from the depth of 1 m. A laboratory sample had a volume of 1 dm^3. The collected water was preserved in the place of collection by addition of the nitrous acid (V) in the amount of 2 cm^3 for each 100 cm^3 of water and then samples were transported to a laboratory. *Spicara maena* L. and Mezgit *Merlangius euxmus* L. were caught in June 2017. Fish were caught with the use of a net. From each bay 15 fish of each specimen were caught. The mass of fish caught in the tests was within the range 15-31 g and their length was 11-18 cm. Fish came from the last year spawning and were not mature and their age was established as 1 year. From fish organs were prepared (muscles, gills, gonads. liver). The choice of those organs was justified with their usefulness in the assessment of environment with bioindicative methods and analytical possibilities (Łuczyńska et al., 2018). Water samples were collected from the same places. A laboratory sample with the volume of 1 dm^3 consisted of approximately 10 original samples. A group samples constituted a sum of original samples.

Table 1. Statistical parameters of elements analysis

Parameter	Cd	Cr	Cu	Fe	Mn	Ni	Pb
Length of waves, nm	228,802	267,707	327,393	238,204	257,608	231,604	220,353
Limit of detection, $\mu g \cdot dm^{-3}$	0,021	0,061	0,045	0,032	0,014	0,0105	0,046
Content in the attes, $mg \cdot kg^{-1}$	0,189	0,73	3,28	146	3,52	0,6	0,12
Measured, $mg \cdot kg^{-1}$	0,179	0,71	3,38	154	3,37	0,567	0,126
Retrieved, %	94,71	97,26	103,05	105,48	95,74	94,56	104,59

The collected water was preserved in the place of collection by addition of the nitrous acid (V) in the amount of 2 cm^3 for each 100 cm^3 of water and then samples were transported to a laboratory. In a laboratory, water samples were condensed tenfold by evaporation. Laboratory samples were subjected to mineralization when wet in the closed system with the use of microwave energy with the use of a microwave system by Anton Paar Multivawe 3000. Analytical portion was 0.5 g per dry mass. Biological material was solved in the mixture of HNO_3 and H_2O_2 in a proportion 5:1 (v/v). Concentration of the investigated elements in the obtained solutions and in water was determined with the element method of absorption spectrometry with electronic atomisation in the apparatus M6 by Thermo. Uncertainty of measurement of the use methods was 8%. For control of the correctness of analysis a certified material of liver reference was applied IAEA-407, from IAEA Reference Materials. Statistical parameters of analysis of certified materials and waves lengths and limits of detection (LOD) were placed in Table 1. The obtained results of average element content were compared with T test at the level of significance p=0.05. Based on the obtained results a coefficient of bio-accumulation of particular elements was calculated. Coefficient of bio-accumulation was calculated by division of the element concentration in dry mass of organs used in the experiment by the content of these elements in water, using a formula

$$BF = Cl / Cw,$$

where:
BF – bioaccumulation factor,
Cl – element concentration in organs dry matter,
Cw – element content of in water.

3. Results and discussion

Results show a higher average content of chromium, iron, manganese, and nickel in water collected from Balaklava Bay compared to the samples collected from the region of Karantinna Bay. The copper content was comparable in samples from both locations, while water from Karantinna Bay included twofold more lead and threefold more cadmium in comparison to the sample from Balaklava Bay (Table 2).

Table 2. Content of selected elements in water collected from the investigated bays (average of 5 samples)

Region	Cd	Cr	Cu	Fe	Mn	Ni	Pb
	($\mu g \cdot dm^{-3}$)						
Balaklava	0,172a	3,891a	16,55a	885,6b	12,32b	3,787b	14,56a
± SD	0,048	0,896	2,523	46,69	2,596	0,458	3,985
Karantinna	0,511b	3,056a	17,85a	625,5a	6,488a	2,454a	11,23a
± SD	0,089	0,423	3,011	51,06	1,896	0,328	2,196

Different letters at mean values indicate the statistically significant differences between the samples from each of the bays at $p = 0.05$.
SD – standard deviation

In case of all the investigated elements, except for iron, their concentration on the level that indicates anthropogenic enrichment, was reported. A natural content of cadmium, copper, chromium, and zinc in sea water is respectively 0.02; 0.1; 0.2; 0.1 $\mu g \cdot dm^{-3}$ (Bandara et al., 2010; Liang et al.., 2018; Kahle and Zauke, 2003). Sanders et al., (2012) provide that a concentration of manganese in water of Sepetiba Bay in Brazil in the region of anthropogenic influence at the level of ca. 2.5 $\mu g\ Mn \cdot dm^{-3}$.

Table 3. Arithmetic average content of investigated elements in organs of fish from Balaklava Bay (average of 15 samples)

Blotched picarel	Cd	Cr	Cu	Fe	Mn	Ni	Pb
	(mg·kg^{-1})						
Gills	**0.425**	**3.494**	**11.34**	**222.2**	**15.07**	**13.24**	**1.804**
± SD	0.322	1.91	8.085	80.65	4.885	1.885	0.998
tissue	**0.360**	**4.822**	**5.465**	**47.35**	**2.644**	**7.301**	**1.300**
± SD	0.102	0.675	1.583	15.00	1.766	3.749	0.742
GM	**0.208**	**5.008**	**14.31**	**71.46**	**1.418**	**7.853**	**1.040**
± SD	0.011	1.463	4.049	26.85	0.332	5.581	0.882
GF	**0.682**	**4.915**	**17.46**	**98.04**	**4.343**	**8.340**	**1.009**
± SD	0.282	1.516	2.187	32.52	0.272	5.293	0.741
Liver	**3.238**	**2.925**	**21.60**	**236.6**	**4.434**	**4.647**	**0.867**
± SD	1.145	1.016	12.98	64.59	0.505	1.549	0.356
Mezgit							
Gills	**0.852**	**6.284**	**12.48**	**182.8**	**15.08**	**7.261**	**1.585**
± SD	0.429	1.668	5.931	88.95	0.617	2.772	0.628
tissue	**0.595**	**5.331**	**4.230**	**91.20**	**4.239**	**6.958**	**1.488**
± SD	0.211	1.202	1.918	26.98	0.711	3.485	0.544
GM	**0.462**	**5.9569**	**13.27**	**81.36**	**1.789**	**7.125**	**0.985**
± SD	0.182	1.563	4.231	34.72	0.328	3.110	0.529
GF	**0.896**	**4.8965**	**18.65**	**113.6**	**2.156**	**8.652**	**0.911**
± SD	0.357	1.056	5.296	41.09	0.411	1.008	0.663
Liver	**3.326**	**3.125**	**23.26**	**244.3**	**3.885**	**5.231**	**1.235**
± SD	1.655	1.028	9.615	86.32	0.423	2.538	0.618

SD – standard deviation

Table 4. Arithmetic average content of investigated elements in organs of fish from Karantinna bay (average of 15 samples)

Blotched pica-rel	Cd	Cr	Cu	Fe	Mn	Ni	Pb
	(mg·kg^{-1})						
Gills	**0.206**	**9.319**	**9.194**	**250.7**	**16.97**	**13.98**	**1.764**
±	0.015	1.435	1.896	28.96	2.213	1.332	0.236
Tissue	**0.409**	**4.371**	**7.587**	**41.24**	**2.694**	**6.293**	**1.070**
±	0.049	0.512	0.912	6.229	0.311	0.811	0.123
GM	**0.105**	**4.966**	**11.53**	**83.08**	**1.948**	**5.130**	**0.804**
±	0.011	0.596	1.965	10.89	0.253	0.621	0.0962
GF	**1.067**	**5.715**	**8.704**	**125.9**	**4.094**	**8.908**	**1.580**
±	0.096	0.689	1.59	15.98	0.543	1.266	0.205
Liver	**2.158**	**2.533**	**19.23**	**244.9**	**4.142**	**4.632**	**1.229**
	0.259	0.198	3.19	36.89	0.509	0.563	0.182
Mezgit							
Gills	**0.524**	**5.849**	**9.644**	**142.5**	**1.281**	**9.545**	**1.281**
±	0.046	0.511	2.085	19.56	0.150	1.326	0.163
tissue	**0.369**	**5.578**	**7.252**	**44.33**	**14.52**	**11.22**	**1.050**
±	0.042	0.688	1.931	5.235	1.536	1.463	0.112
GM	**0.223**	**5.116**	**13.65**	**92.33**	**2.245**	**8.756**	**0.775**
±	0.029	0.462	1.658	11.06	0.268	1.236	0.089
GF	**0.986**	**6.235**	**7.986**	**103.7**	**4.652**	**7.685**	**1.326**
±	0.106	0.698	1.44	14.56	0.596	0.896	0.209
Liver	**2.236**	**2.896**	**21.52**	**268.4**	**3.885**	**5.162**	**1.445**
±	0.289	0.315	2.963	34.23	0.423	0.623	0.209

SD – standard deviation

Copper and cadmium content in water from Baya Bay in the region of the increased anthropopression was determined at the level of respectively 2.4 and 0.2 μg·dm^{-3} (Qiu et al., 2011). The research area (Balaklava and Krantinna Bay) includes areas with the increased anthropopression. Niemiec et al., (2018) carried out research related to bioaccumulation of heavy metals in fish larvae in several bays of Sevastopol. Those authors found the content of nickel in water from Karantinna Bay in 2012 at the level of ca. 4 μg·dm^{-3}, of lead at the level of ca. 19 μg·dm^{-3} and zinc 55 μg·dm^{-3}. Those authors reported a great variability of content of the investigated elements in various bays in the region of Sevastopol. The authors' own research shows slight differences of concentration of the tested elements in waters from both investigated bays. The content of elements in water and other elements of a biotype is not a credible source of information related to a threat to the ecosystem and for consumers of aquaculture products. Fish constitute a principal element of a diet in many regions of the world and macroelements and trace elements include there may negatively influence people (Bonsignore et al., 2018).

The average content of cadmium in tested water organisms was from 0.105 to 3.326 mg·kg^{-1}. The content of chromium was within 2.533 to 9.319 mg·kg^{-1}. Amount of copper in particular organs of tested fish was within 4.23 to 21.523 mg·kg-1, of iron from 41.2 to 268.4 mg·kg^{-1}, manganese from 1.418 to 16.97 mg·kg^{-1}. Nickel content was reported within 4.647 to 13.98 mg·kg^{-1} (Table 3 and 4). Results of the research show a slightly higher, average for all organs cadmium content in blotched picarel fish in comparison to fish from the whiting species. In case of the remaining elements, no differences of concentration of the content of elements between both fish species were reported. Both species belong to benthos eating fish. They live in similar ecological niches, in seaside regions where they cover underwater meadows. They eat similar organisms living on the bottom. A type of the food they eat, and a living strategy of fish is one of the main elements that influence the level of bioaccumulation of trace elements. Velusamy et al., (2014) concluded a strong dependency between the place of living of fish and the type of the collected food and the level of bioaccumulation of trace elements in them. Those authors concluded in majority of cases a higher concentration of trace elements in benthos fish in comparison to the fish species that live in the pelagic zone. Similar relations were reported by El-Moselhy et al., (2014) in case of several fish caught in the Red Sea.

The highest content of cadmium and copper in case of both fish species were found in liver. The content of cadmium in those organs was more than 3 mg·kg^{-1} for fish caught in Balaklava Bay and ca. 2 mg·kg^{-1} in fish from Karantinna Bay. In case of copper no differences in the content of this element in fish liver from particular locations were reported. The content of this element was ca. 20 mg Cu·kg^{-1}. Cadmium content in gills and muscles was ca. eightfold lower in comparison to the content of this element in liver. Content of this element in ovaries was ca. half lower than in testicles of the investigated fish. In case of copper, its content in gills and testicles was considerably lower than in liver. El-Moselhy et al., (2014) show similar relations of the amount between the copper content in liver, muscles, and gills. The highest content of chromium and copper in all investigated locations was found in gonads of the investigated fish (Table 2 and 3). In the authors' own research, a higher impact of the location in comparison to a fish species used in the tests was confirmed. In general, cadmium content in liver of the investigated fish was high which indicates a threat for water organisms. El-Moselhy et al., (2014) observed lower cadmium content in liver of various species of fish from the Red Sea in comparison to the results obtained in own research, the amount of copper provided by those authors was comparable to the results of own research. A comparable content of copper was reported by Anandkumar et al., (2018) in muscles and gonads of several pelagic fish species from Borneo. The highest concentration of nickel, lead, iron, and manganese was reported in gills of the investigated animals (Table 2 and 3). The amount of nickel in gills was on average twofold higher than in other organs. Anandkumar et al., (2018) et al., say that the content of nickel in gills of several fish species from Borneo was at a higher level than in the content of this element in gonads, muscles, and liver. The average amounts of the investigated elements from the lowest were as follows: Pb<Cd <Cr<Mn<Ni<Cu<Fe. In gonads these relations were as follows Cd<Pb<Mn<Cr<Ni<Cu<Fe, while in muscles and gills Cd<Pb<Cr<Mn<Cu< Ni<Fe and Cd<Pb<Cr<Cu<Ni<Mn<Fe. Cadmium, copper, and iron content in particular organs of the investigated fish were from the lowest in particular fish organs. On average more of this element was found in fish caught in Balaklava Bay than in Karantinna Bay.

It was also concluded that the content of elements is high and characteristic for polluted environments. In no case, however, critical values for fish muscles for food purposes were not exceeded (WHO 1989). According to Rahman et al., (2012) the content of cadmium in muscles of various fish species from the polluted regions of Bangladesh are within 0.09 to 0.87 mg Cd·kg^{-1} s.m. Qiu et al., (2011) concluded that the content of copper and lead in predatory fish muscles from Baya Bay in China in the region of an increased anthropopression was at the level of respectively 4.4 and 1.2 mg·kg^{-1}. The content of copper, lead, cadmium and manganese of Sargocentron spiniferum fish liver caught in the polluted regions of the Red Sea were respectively: 10 mg·kg^{-1}; 0.6 mg·kg^{-1}; 1.8 mg·kg^{-1}; 550 mg·kg^{-1} and 4.5 mg·kg^{-1} (El-Moselhy et al., 2014) say that the content of copper in gills of various species of fish from the Red Sea was at the level of approximately ca. 3 mg·kg^{-1} per dry mass. The content of this element in muscles was determined at the level of ca. 1 mg·kg^{-1}. Moreover, they observed the highest content of copper, cadmium, and iron in liver of the investigated fish. In case of lead and manganese the highest content was observed in fish gills. Yousuf et al., (2000) provide the content of copper in fish muscles from the family of Lethrinidae caught in the region of Arabian Bay in the places of the increased anthropopression at the level of ca. 0.8 mg Cu·kg^{-1} per dry mass. Canli and Atli (2003) provide the content of copper, lead and chromium in fish muscles caught in the Mediterranean Sea at the coast of Turkey within the range of 19-30 275 mg Fe·kg^{-1}; 2.19-4.17 mg Cu·kg^{-1}; 2.98-6.12 mg Pb·kg^{-1} and 1.24-2.42 mg Cr·kg^{-1}. The content of these elements in gills and liver were also lower than the ones concluded in the own research. The location of Sevastopol in the region of several bays influenced formation in each of them of ecosystems with specific conditions shaped mainly by the level and directions of anthropopression (Kuzminova et al., 2014), Karantinna Bay is located in the region of the strongest anthropopression in the region of Sevastopol. While, in the Balaklava Bay a raised anthropogenic pression related to sailing is observed. (Pavlova et al., 2007). The direct disposal of sewage to their waters is lower than in Karantinna Bay.

The value of the bioaccumulation coefficient was expressed as a relation of the content of the element in dry mass of particular organs and in water. Values of the bio-accumulation ratios in organs used in the tests were within 53.47 to 19337 (Fig. 1-5). The lowest value of this parameter was observed in case of lead and iron, for which the average values of this parameter were respectively 96.85 and 190.1 due to a relatively high content of these elements in water. The highest values of the bio-accumulation ratio were observed in case of cadmium and nickel, respectively 4040 and 2668. The value of the bio-accumulation ratio of chromium in muscles of Acanthurus blotched caught in coast regions of Iran was 185 (Alhashemia et al., 2012).

Qiu et al., (2011) Provide values of the bio-accumulation ratio of copper at the level of 4000, while lead at the level of ca. 2000 in fish in Baya Bay in the region of the increased anthropopression. Rajeshkumar et al., (2018) found that the value of the bio-accumulation ratio in muscles of goldfish from Taihu lake in China at the level of ca. 2000 for chromium, while for copper the value of this parameter was ca. 1000. Those authors carried out the research in the regions of the low level of anthropopression.

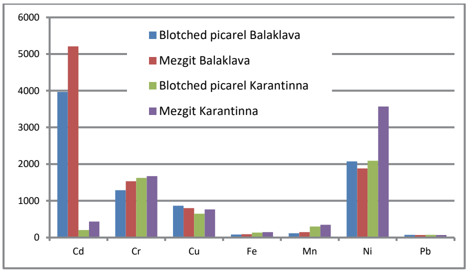

Fig. 1. Bioaccumulation ratio in fish gills

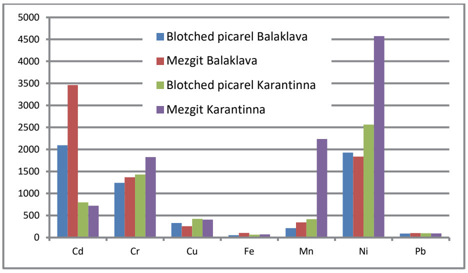

Fig. 2. Bioaccumulation ratio in fish muscles

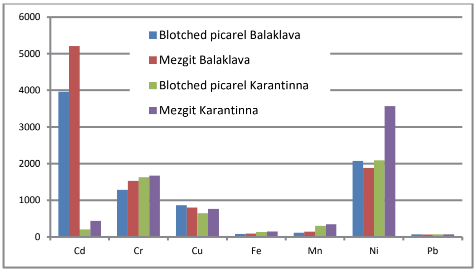

Fig. 3. Bioaccumulation ratio in fish testicles

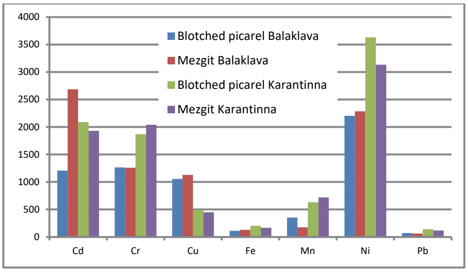

Fig. 4. Bioaccumulation ratio in fish ovaries

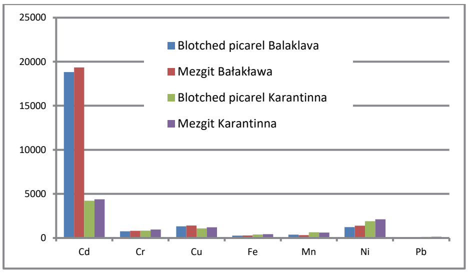

Fig. 5. Bioaccumulation ratio in fish liver

The bio-accumulation ratio is an important ratio of the environmental threat of xenobiotics. The coefficient of bio-accumulation of cadmium in Cyphocharax voga muscles, sweet water benthic eating fish living in not-cleaned region was 778 in relation to the content of this element in water. In the polluted environment, the value of this parameter was 428.4. On the other hand, the bio-accumulation ratio of this element in muscles of Oligosarcus sp., of the fish living in the contaminated region was 667, while in the polluted region this value was at the level of 111.1 (Weber et al., 2013). Those authors pay attention to a higher value of the bio-accumulation ratio in fish from polluted regions. The value of the bio-accumulation ratio of iron and manganese in *Centropomus parallelus* fish muscles from the estuary in Brazil was respectively*:* 57.93 and 40.68 (Souza et al., 2013). These are lower values than the ones obtained in own research. *Even lower values of the bioaccumulation ratio of manganese are provided by* Adhikari et al., (2009), at the level of ca. 8.03.

4. Conclusions

1. Water from the investigated bays of Sevastopol included the investigated elements in the amounts that indicated anthropogenic enrichment in these elements.
2. Higher contents of manganese iron and nickel were reported in water of Balaklava Bay. Only in case of cadmium, its content was statistically higher in water from Karantinna Bay. There were no differences in the content of the remaining elements in water.
3. Higher differences of the content of the investigated elements in particular organs of fish due to the location in comparison to the species. The highest content of cadmium, chromium and manganese in fish larvae were found in samples collected from Karantinna Bay, copper from Omega Bay, while iron in organisms caught in Gałabuja Bay.
4. Concentration of the investigated elements in fish liver was from the lowest Pb<Cd<Cr<Mn<Ni<Cu<Fe. In case of gonads , both testicles and ovaries, these contents were as follows Cd<Pb<Mn<Cr<Ni<Cu<Fe, while in muscles and gills respectively Cd<Pb<Cr<Mn<Cu<Ni<Fe and Cd<Pb<Cr<Cu <Ni<Mn<Fe.
5. The content of all investigated elements in particular organs of fish were high, characteristic for ecosystems changed into anthropogenic.
6. From the point of view of a possibility of using particular fish for consumption, exceeding of the content of the investigated elements was not reported.
7. The value of the bio-accumulation ratio of the investigated elements in tested fish organs was from the highest as follows: Cd>Ni>Cr>Mn> Cu>Fe>Pb.

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Abstract

The objective of the paper was to assess the trace elements content (Cd, Cu, Cr, Fe, Mn, Ni and Pb) in gills, muscles, gonads and liver in two fish species from two bays (Karantinna and Balalaklava) in the region of Sevastopol. Concentration of the investigated elements in the obtained solutions and water were determined with the absorption atomic spectrometry method with electro-thermal atomization. Levels of heavy metals differed in two locations. Differences due to fish species were slight. Water from both locations included the investigated elements in the amounts that indicated anthropogenic enrichment. Concentration of the investigated elements in fish liver was in the order from the lowest Pb < Cd < Cr < Mn < Ni < Cu < Fe. In case of gonads, the content was in the order Cd < Pb < Mn < Cr < Ni < Cu < Fe, while in muscles and gills it was respectively Cd < Pb < Cr < Mn < Cu < Ni < Fe and Cd < Pb < Cr < Cu < Ni < Mn < Fe. The concluded contents of all investigated elements in particular fish organs were characteristic for ecosystems changed into anthropogenic. Critical values of the concentration of the investigated metals in muscles were not exceeded from the point of view of fish use for food.

Key words:
trace elements, bioaccumulation, fish, sea bays, Sevastopol

Zawartość Cd, Cu, Cr, Fe, Mn, Ni i Pb w wodzie oraz wybranych organach ryb z gatunku Pysoń wygrzbiecony *Spicara maena* L. oraz Mezgit *Merlangius euxmus* L. z Zatoki Karantinna i Bałakława w rejonie Sewastopola

Streszczenie

Celem pracy była ocena zawartości pierwiastków śladowych (Cd, Cu, Cr, Fe, Mn, Ni i Pb) w skrzelach, mięśniach, gonadach i wątrobie w dwóch gatunkach ryb pochodzących z dwóch zatok (Karantinna i Bałakława) zlokalizowanych w okolicach Sewastopola. Stężenie badanych pierwiastków w uzyskanych roztworach oraz w wodzie oznaczono metodą atomowej spektrometrii absorpcyjnej z atomizacją elektrotermiczną. Poziomy metali ciężkich różniły się pomiędzy obydwiema lokalizacjami. W mniejszym zakresie zaobserwowano zróżnicowanie ze względu na gatunek ryb. Woda z obydwu lokalizacji zawierała badane pierwiastki w ilościach wskazujących na antropogeniczne wzbogacenie. Concentration of the investigated elements in fish liver was from the lowest Pb<Cd<Cr<Mn<Ni<Cu<Fe. W przypadku gonad, zawartości kształtowały się w kolejności Cd<Pb<Mn<Cr<Ni<Cu<Fe, natomiast w mięśniach i skrzelach odpowiednio Cd<Pb<Cr<Mn<Cu<Ni<Fe i Cd<Pb<Cr<Cu<Ni<Mn<Fe. Stwierdzone zawartości wszystkich badanych pierwiastków w poszczególnych organach ryb były charakterystyczne dla ekosystemów przekształconych antropogenicznie. Nie stwierdzono przekroczenia wartości krytycznych stężenia badanych metali w mięśniach ryb, z punktu widzenia możliwości ich wykorzystania na cele spożywcze.

Słowa kluczowe:
pierwiastki śladowe, bioakumulacja, ryby, zatoki morskie, Sewastopol