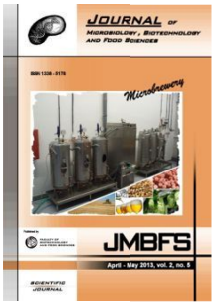

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THE DISTRIBUTION OF CADMIUM AND COPPER IN FISH ORGANS

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ABSTRACT

The aim of this study was to describe the distribution of cadmium and copper in selected organs of white bream (*Blicca bjoerkna*) living in Nida river and Vistula river. Elements were determined by atomic absorption spectrophotometry (AAS). The obtained results showed that all organs of the fish from Vistula River had higher level of cadmium and copper than organs of fish from Nida River. The highest level of cadmium was in the kidneys>gills>liver>dorsal muscles and gonads. In the case of copper the highest level was in liver>kidneys>gills>gonads>dorsal muscles.

Keywords: Fish, white bream, AAS, cadmium, copper, organs

INTRODUCTION

The environmental pollution and its biodegradation are the aim of the scientific research of scientists throughout the world. The air, soil and Earth pollution has got a big influence on the functionality of living organisms. One of the factors which impact on the environmental pollution is the function of heavy metals among which we can single out biogenic elements as well as xenobiotic elements.

Cadmium and copper are chemical elements which belong to heavy metals. However their properties and functions are very different. Copper is a biogenic element which fulfils significant functions in living organisms, whereas cadmium is a xenobiotic element which is harmful to organisms.

Annual cadmium emission into the environment on a global scale is 3.3 – 14.6 thousand tons, with up to 90% is taken from human activities (**Orłowski, 2008**). Cadmium gets to the organism mainly by the digestive and respiratory track and by skin. The biggest amount of this element gets to the organism by the respiratory track. In humans, the place in which the absorption of cadmium is in the largest quantity is the initial segment of bowel (**Orłowski, 2008**). Cadmium leaks from the respiratory or digestive tract to the blood and involves macromolecular proteins and accumulates in the liver. Cadmium in the liver liberates from the macromolecular proteins because of their biodegradability and links with metallothionein. Metallothionein is responsible for detoxification processes and for the transport of trace elements (e.g Cu, Zn) as well as xenobiotic elements (e.g Cd) excluding them from the metabolism (**Jarosz, Połeć-Pawlak, 2003**). The largest accumulation of cadmium in animals occurs in the kidneys and the liver (**Mochizuki, et al., 2008**). Research conducted by Swedish scientists has shown that smoking tobacco at the cadmium concentration in the blood is increased almost twice (**Nordberg, et al., 2000**). Large quantities of cadmium are also accumulated in the respiratory organs such as the gills of fish (**Rashed, 2001**) or the lungs of large mammals such as wild boar or bear (**Medvedev, 1999**). In addition to the listed organs cadmium was detected also in thyroid, pancreas, bone and muscles of human (**Uetani, et al., 2006**).

Copper as a microelement is found in trace quantities in all animal tissues acting an essential element to the proper functioning of the body. Copper is essential to process of hemoglobin synthesis, as a coenzyme it falls in the composition of certain enzymes involved in redox processes. It is a component, inter alia, of ceruloplasmin (EC 1.16.3.1) – plasma protein which regulates metabolism and transport of iron, cytochrome c oxidase (EC 1.9.3.1) taking part in transport of electrons, tyrosinase (EC 1.14.18.1) involved in the process of melanin production, lysine oxidase (EC 1.4.3.13) which takes part, inter alia, in collagen fibers synthesis, dopamine beta – monooxygenase (EC 1.14.17.1) which takes part in the synthesis of peptide hormones, superoxide dismutase (EC 1.11.1.6) which takes part in the protection of aerobic organisms against cytotoxic activity of superoxide, and peptidyl α-amidating monooxygenase (PAM) (EC 1.14.17.3) taking part in the catalysis of incorporating an oxygen atom to the hydroxyl substrate (**Mercer, 2001**).

It is considered that the tissues of certain animals have a particular tendency to collect copper. The highest level of copper was found in invertebrates - in the blood of annelids, crustaceans and molluscs, where it is a component of hemocyanins (**Kabata – Pendias, Pendias, 1999**). In vertebrate animals, high copper content was found, inter alia, in the liver of birds (**Eun – Young, et al., 1996**), human milk (**Dorea, 2000**), muscles of dolphin (**Wood, Van Vleet, 1996**), kidneys of rat (**Cui, Okayasu, 2008**) and gills of fish (**Romeo, et al., 1999**).

The aim of the study was to identify and compare in what quantities cadmium and copper occur in selected organs of white bream from both rivers.

MATERIAL AND METHODS

The study involved 30 females of white bream (*Blicca bjoerkna*). The fish were caught in two rivers in the south of Poland, 15 specimens from Nida River and 15 specimens from Vistula River. From all caught alive fish were dissected samples (1g) of fresh weight. The samples were dissected from particular organs such as liver, kidneys, gills, gonads, and muscles. Taken organs were dried at $105^{O}C$ in order to obtain dry mass of organs. Next the material was mineralized in concentrated nitric acid (HNO_3) at the temperature of $90^{O}C$ until complete dissolution of tissues using VELP Scientifica DK 20 mineralizator. Next the samples were thinned with spectrally pure water to cubic capacity of 10 ml. The samples obtained this way were analysed for the content of cadmium and copper, which were assayed with atomic absorption spectrophotometry (AAS) in a Cole – Palmer, BUCK 200A apparatus. The results were subjected to statistical analysis using the STATISTICA software involving ANOVA tests and post hoc Tuckey analysis.

Results distribution was checked by Shapiro – Wilk's test. Homogeneity of variance was checked by Levene's test. Statistical significance was defined at $P < 0.05$.

The content of studied elements in water and bottom sediment from both rivers was compared on the basis of the information received from Voivodship Inspectorate for Environmental Protection in Cracow (WIOŚ Krakow) and WIOŚ Kielce.

Table 1 Cadmium and copper content in water and bottom sediment of Vistula and Nida River according to WIOŚ Kraków i WIOŚ Kielce

River	Metal	Water	Sediment
Wisła	**Cd**	0.00039 mg Cd•L^{-1}	2 mg•kg^{-1}
Nida		0.000078 mg Cd•L^{-1}	<0.5 mg•kg^{-}
Wisła	**Cu**	0.0027 mg Cu•L^{-1}	12 mg•kg^{-1}
Nida		0.0013 mg Cu•L^{-1}	4 mg•kg^{-1}

RESULTS

Cadmium

The highest medium cadmium content – 5.944±0.405 mg•kg^{-1} d.m was in kidneys of white bream caught alive in Vistula River, lower in gills 4.688±0.980 mg•kg^{-1} d.m > liver 1.859±0.385 mg•kg^{-1} d.m > gonads 0.522 ±0.126 mg•kg^{-1} d.m > dorsal muscles 0.473±0.026 mg•kg^{-1} d.m. Very similar was the concentration of cadmium in organs of fish caught alive in Nida River, where the highest content of this element was found also in kidneys 5.818±0.298 mg•kg^{-1} d.m > gills 2.511±0.138 mg•kg^{-1} d.m > liver 1.613±0.132 mg•kg^{-1} d.m > dorsal muscles 0.593±0.028 mg•kg^{-1} d.m > gonads 0.318 ± 0.040 mg•kg^{-1} d.m.

There was statistical significance between cadmium content in gills of fish from the Vistula and Nida ($p = 0.047$). There was also statistical significance in cadmium content in fish coming from the Nida between kidneys and liver, gills, muscles and gonads ($p = 0.000$), between gills and muscles ($p = 0.016$) and between gills and gonads ($p = 0.006$).

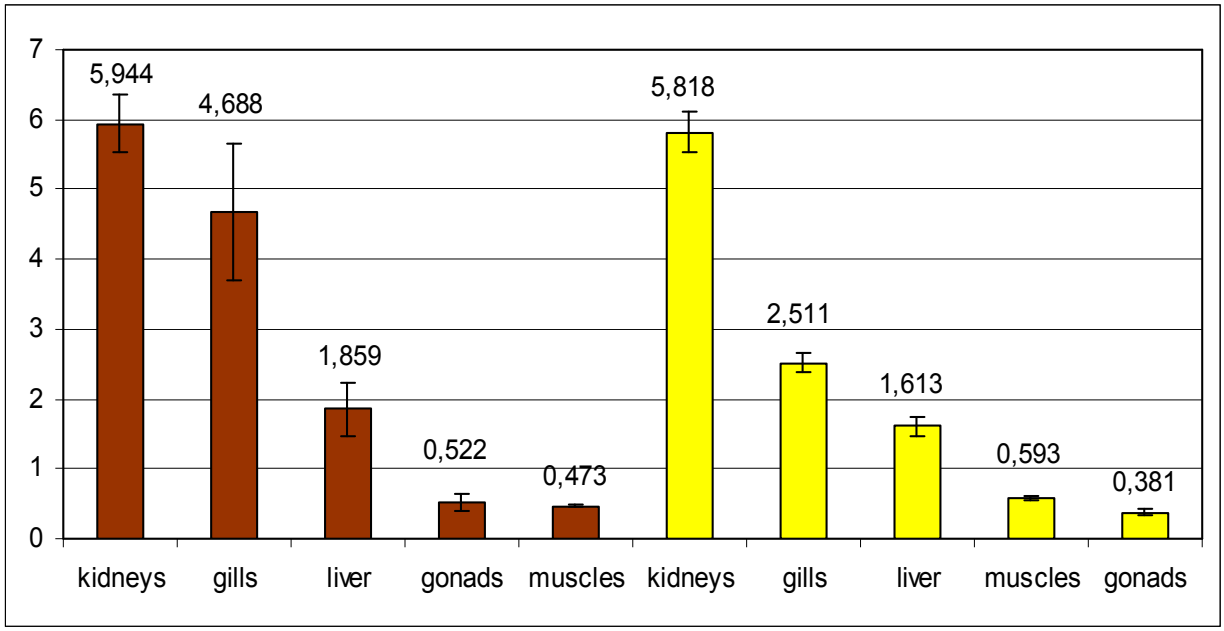

Figure 1 Cadmium content in organs of white bream coming from Vistula and Nida River expressed in mg•kg^{-1} d.m. ± standard error (SE)

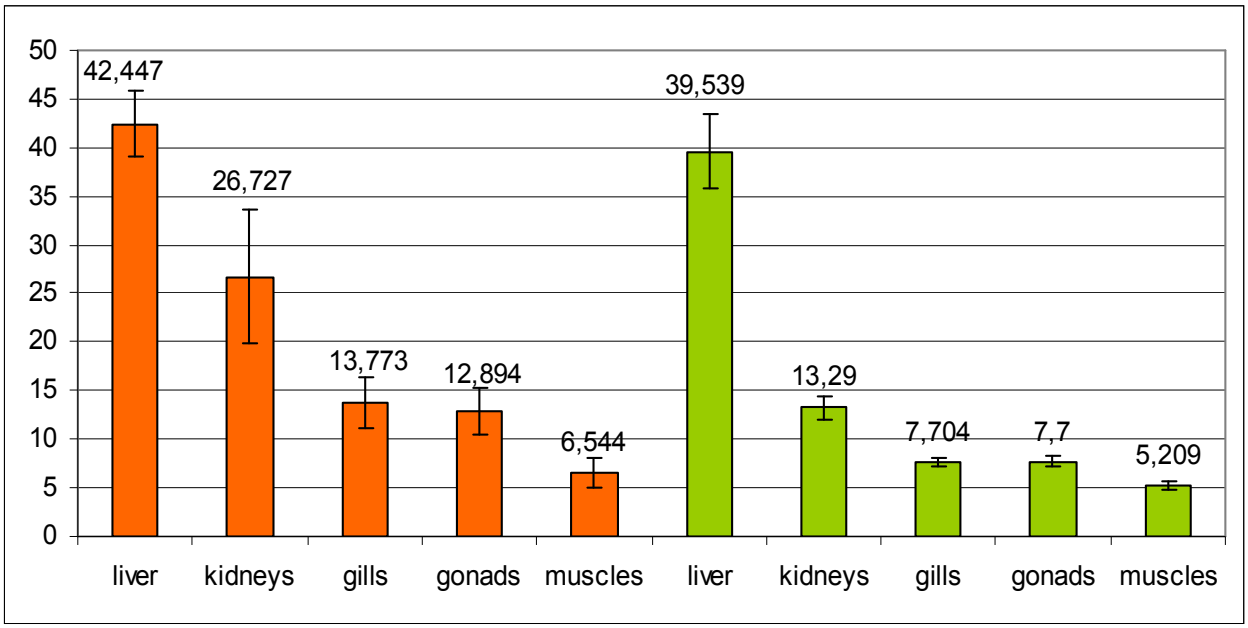

Figure 2 Copper content in organs of white bream coming from Vistula and Nida River expressed in mg•kg^{-1} d.m. ± standard error (SE).

Copper

The higest concentration of copper was fund in the liver of white bream coming from the Vistula and it was 42.447±3.339 mg•kg^{-1} d.m., in kidneys 26.727±6.920 mg•kg^{-1} d.m lower in gills 13.773±2.646 mg•kg^{-1} d.m., in gonads 12.894 ± 2.472 mg•kg^{-1} d.m and the lowest in dorsal muscles 6.544±1.443 mg•kg^{-1} d.m. In the case of fish caught alive in the Nida copper content in examined organs was similar like in fish from the Vistula. The highest content was found also in the liver 39.539±3.831 mg•kg^{-1} d.m > kidneys 13.290±1.192 mg•kg^{-1} d.m > gills 7.704±0.419 mg•kg^{-1} d.m > gonads 7.700 ± 0.578 mg•kg^{-1} d.m > dorsal muscles 5.209±0.369 mg•kg^{-1} d.m.

There was not any statistical significance in copper content between organs of fish coming from Vistula and Nida River.

There was statistical significance in copper content between the liver and other organs in white bream caught alive in Nida River ($p = 0.000$).

DISCUSSION

On account of difference between the nature of the rivers from which the examined fish came and currently in force opinion that the Vistula is a heavily polluted river, higher concentrations of studied elements was expected in the organs of fish coming just from the Vistula.

The highest concentration of studied elements was expected in the liver and kidneys, because they are organs in which takes place the process of detoxification, as well as in gills which are the respiratory organ. In the studies dissected gonads and muscles, in which the concentration of examined metals was expected to be low. Research of different elements content in dorsal muscles of fish is particularly important for their consumption by human.

Cadmium accumulation in the organs of white breams caught in the Vistula was higher than in the organs of fish from the Nida except for the dorsal muscles, in which higher cadmium concentration was indicated in the fish coming from Nida River.

Similarly all examined organs of white breams caught in Vistula River contained more copper than organs of white breams coming from Nida River.

According to many authors the lowest cadmium content is in the dorsal muscles (**de Conto Cinier, et al., 1999; Afonso, et al., 2007**). In my research I also found this regularity. My research showed that cadmium concentration in the dorsal muscles was the lowest among examined organs. Similar results were obtained by **de Souza Lima Junior, et al., (2002)** studying cadmium content in organs of four species of fish, *Mugil lisa, Cynocin leiarchus, Micropogonias furnieri, Genidens genidens*.

Some data described in the literature shows that low cadmium concentration is also found in the gonads. **De Souza Lima Junior, et al., (2002)** studying the concentration of this element in the organs of fish *Mugil lisa, Cynocin leiarchus, Micropogonias furnieri, Genidens genidens* from Brasil found that it was similar like in the muscles and lower than in the liver.

The low cadmium content in the gonads can be explained by the specific function of this organ. Gonads, as a place where the gametes are produced, have got a number of mechanisms protected them against the influence of external conditions. Contamination of gonads, and thus their impairment, or reduction of number of produced gametes, to a large extent make an impact of production of healthy or live offspring (**Lienesch, et al., 2000**). Cadmium has an unfavourable influence of quality of sperm and reduces the diameter of seminiferous tubules (**Massanyi, et al., 2000**). It also make an unfavourable impact of ovaries, what was found in the study on rabbits *Oryctolagus cuniculus*. Under the influence of cadmium the number of ovarian follicles is reduced and their maturation is speeded up (**Massanyi, et al., 2001**).

Phenomenon of cadmium accumulation in the gills of animals is widely known. Presence of this metal was also found both in the gills of invertebrate and vertebrate animals (fish, amphibians). **Marchenko (2007)**, studying the concentration of this element in the organs of silver crucian carp (*Carassisus auratus gibelio*) found that the amount of cadmium in the gills of fish was lower than in the liver and kidneys, but higher than in the other organs.

Relatively high cadmium content seems to be predictable in the gills which have a direct contact with the metals contaminated environment and which are the way of the infiltration of the metals to the organism.

Whereas the high copper concentration in the liver is connected with its function in the organism and with the fact that this metal ions are built in the apoceluroplasmin in the liver cells. The research conducted by **Wong, et al., (1999)** on the fish *Sparus sarba* similar as my studies showed high copper content in their liver. As well **Romeo (1999)** studying fishes *Serranus scriba, Epinephelus costae, Cephalopholis nigri, Pseudupeneus prayensis* found that copper concentration in their liver was the highest.

The important factor that influences of the pace of absorption of metals through organism is pH of the environment in which they are located. The research conducted on fish *Oreochromis niloticus* demonstrated relationship between pH of the water and copper content in the liver, gills and muscles. However, regardless of the amount of the copper content in the water and pH of the environment, the highest concentration of this element was always in the liver, whereas lower in the gills and muscles (**Cogun and Kargin, 2004**). Cited information is divergent from my observations, because copper content in the muscles of fish, which were examined by me, was very low. It is probably some regularity because as well **Moiseenko and Kudryavtseva (2001)** studying chemical elements content in organs of lavaret (*Coregonus lavaretus*) and brown trout (*Salmo trutta morpha fario*) found the lowest amount of copper in their muscles.

The excess of copper absorbed by organism is accumulated, inter alia, in kidneys. High concentration of this element in kidneys can signify that high amount of it was taken up from food.

Borgmann (1998) demonstrating the model of accumulation of copper in the organism of fish *Hyalella azteca* found that gills are not the place through which a significant number of copper gets to organism of fish. It can be found that low copper content in the gills of examined fish is a natural phenomenon. This thesis is confirmed by **Romeo's** research **(1999)** who demonstrated much lower copper content in the gills and muscles of fishes *Serranus scriba, Epinephelus costae, Cephalopholis nigri, Pseudupeneus prayensis* than in their liver. Similarly in my studies copper accumulation in the gills was quite low, however higher than in the gonads and dorsal muscles of examined fish from both rivers.

Gills constitute one of the pathways of absorption of elements to fish body, therefore above normal value of some metals can be natural phenomenon in this organ.

Based on the obtained results much amount of examined chemical elements in the organs of fish coming from Vistula River from heavily urban areas was confirmed according to the expectations.

CONCLUSION

The liver and kidneys, which are natural filters and centre of metabolic processes of fish organism, contained high amount of the metals. The metals are transported together with metallothionein in both these organs. High concentration of copper in the liver and kidneys is also caused by complexes which are formed in these organs and contain in their composition copper. Whereas higher cadmium content indicates that these organs are the place where detoxification processes take place.

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