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HEAVY METAL POLLUTION OF ECOSYSTEM WITHIN THE MIDDLE COURSE OF THE JIHLAVA RIVER

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Abstract

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The monitoring of the contents of heavy metal pollutants: total Hg, Pb, Cd, Cr, Ni, Cu and Zn in fish muscle, water, bottom sediments and zoobenthos was realised in May and July of 2007 on two localities: Vladislav, upstream the Dalešice and Mohelno dam reservoirs (Czech Republic), and Hrubšice downstream them. Samples of fish muscle were taken from chub (*Leuciscus cephalus*), barbel (*Barbus barbus*) and brown trout (*Salmo trutta* m. *fario*). Water, bottom sediments and zoobenthos samples were taken as representative ones from both localities. The samples were analysed with the apparatus AMA 254, AA-300 and SPECTR AA-30. In water of both sites there was found above-limit (0.1 µg/l) content of mercury (0.99 µg/l Hrubšice, 2 µg/l Vladislav). The bottom sediments in Vladislav were most contaminated by Pb (120.21 mg/kg) and Cr (164.90 mg/kg) and in Hrubšice locality by Ni (90.66 mg/kg). High concentration of Pb (25.84 mg/kg) in Vladislav and of Ni (240.90 mg/kg) and Cr (140.5 mg/kg) in Hrubšice was found in zoobenthos. In the point of view contents of heavy metals in fish muscle tissue, statistically significant ($p < 0.05$) higher content of Hg was found in barbel and chub from Vladislav (0.155 ± 0.012 mg/kg and 0.163 ± 0.064 mg/kg) in comparison with Hrubšice (0.073 ± 0.035 mg/kg and 0.095 ± 0.082 mg/kg) as similarly as the concentration of Cd in chub (0.062 ± 0.140 mg/kg at Vladislav and 0.006 ± 0.002 mg/kg at Hrubšice), whereas the content of Ni in barbel was statistically significantly higher at Hrubšice (0.175 ± 0.042 mg/kg) compared to Vladislav (0.050 ± 0.017 mg/kg). The last significant difference was found in Pb concentrations, when fish from Hrubšice were more contaminated (concentrations 0.155 ± 0.048 mg/kg in barbel and 0.182 ± 0.110 mg/kg in chub) than the same species from Vladislav (contents 0.050 ± 0.017 mg/kg and 0.064 ± 0.005 mg/kg). In theme of consumption risk of the muscle tissue of fish by FAO/WHO, the Hg was limiting factor at both sites. In the locality Vladislav provisional tolerated weekly intake (PTWI) was 1.94 kg in barbel and 1.84 kg in chub. In the Hrubšice it reached 4.12 kg in barbel, 3.15 kg in chub and 5.51 kg in brown trout.

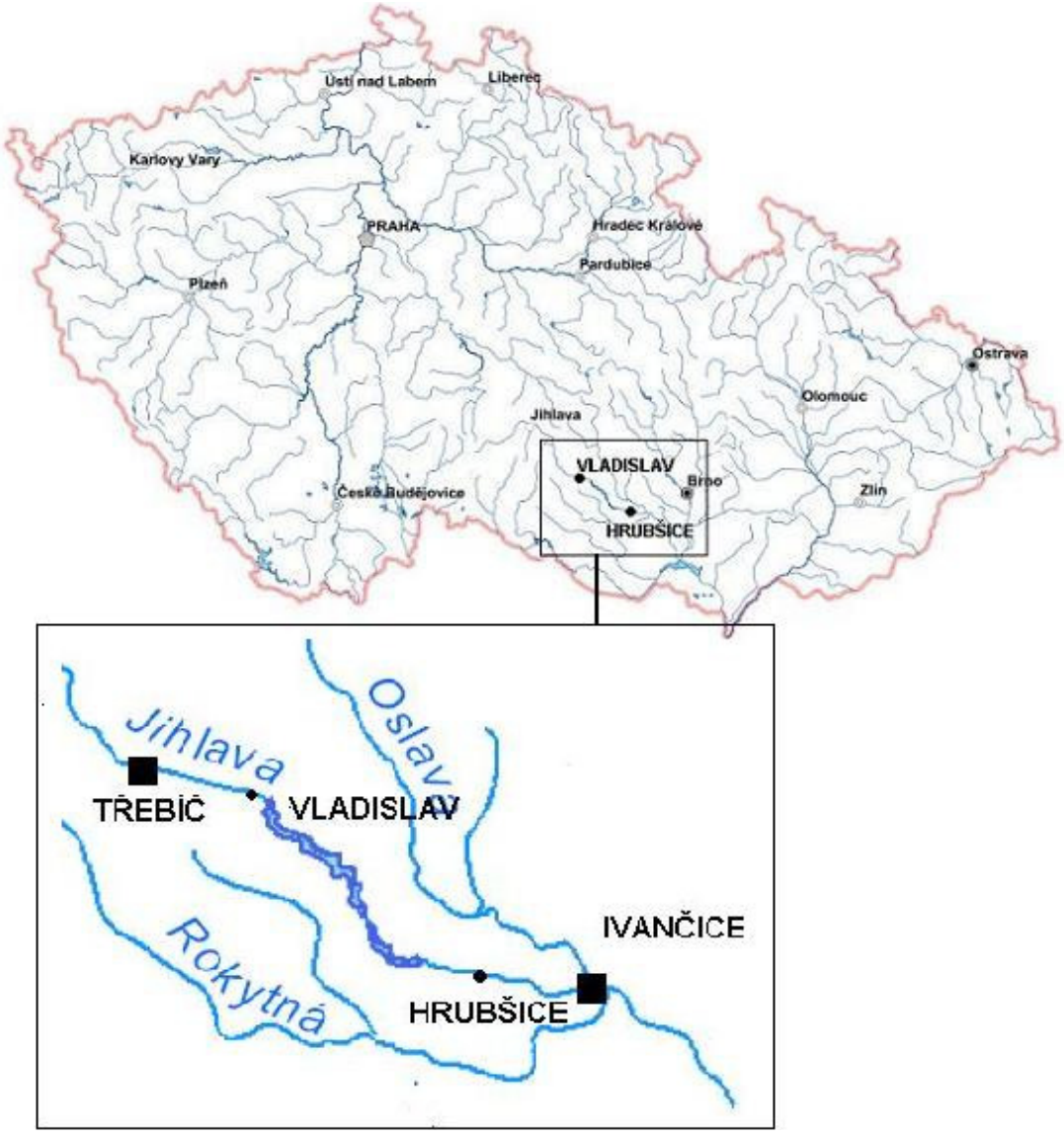
barbel (*Barbus barbus*), chub (*Leuciscus cephalus*), brown trout (*Salmo trutta*), metal contamination

When assessing the level of heavy metal pollution encountered in aquatic environment, we typically determine the contents of specific residues found in water, bottom sediments, zoobenthos and in the fish muscle. The indication procedure relies mostly on fish species living at all sections of watercourses and feeding on a broad range of food (omnivorous) – in the Czech Republic it is primarily the chub (*Leuciscus cephalus*). To eliminate errors possibly caused by different food specializations, different environmental conditions and by the transient physico-chemical parameters of water, a generally accepted practice rests in analysing various fish species (Lange *et al.*, 1993; Burger *et al.* 2002; Sager, 2002). The Jihlava River has already been investigated for the residues of heavy metals gathered in the fish muscle and deposited in the environment (Houserová *et al.*, 2006a,b; Peňáz *et al.*, 2005; Spurný *et al.*, 2002; Spurný *et al.*, 2009). Upstream the Dalešice and Mohelno dam reservoirs the river assumes the character of barbel zone almost approaching the bream zone, while downstream them we encounter a ty-

pical secondary trout zone. This paper aims to assess the contents of heavy metal residues in the fish muscle tissue in the Jihlava River and to compare the contents of such residues found to contaminate the muscle of fish living upstream and downstream the Dalešice and Mohelno reservoirs; and to appreciate the consumption safety of fish caught by anglers at these sites. We have focused analyses on fish muscle tissue as a main part of the fish body consumed by the anglers, in which the concentration of mercury (Hg) and methyl mercury is always the highest (Houserová *et al.*, 2006b). Additionally the content of heavy metals in water, bottom sediments and zoobenthos samples of the Jihlava River was analysed.

MATERIALS AND METHODS

The research was focused on these metals: total mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu) and zinc (Zn). Samples of the water, fish muscle tissue, zoobenthos and the bottom sediments to be analysed for their contents of heavy metals were collected during the growing season of 2007 from two sites located within the middle course of the Jihlava River, the first one (Vladislav), downstream the Třebíč town (GPS location: 49°12'49.219"N, 15°55'50.735"E), situated upstream the Dalešice and Mohelno dam reservoirs and the second site (Hrubšice, GPS location: 49°5'34.896"N, 16°17'16.658"E) downstream the reservoirs (Fig. 1). The sites were once sampled, Hrubšice in 25th May and Vladislav in 15th August 2007. Either of the two samples consisted of water, bottom sediments, zoobenthos and fish. The water samples were taken from the streamline and stored in 1.5l polyethylene bottles. The sediment samples were taken as to represent the entire cross-section of the stream and they were put to



1: *Sampling sites location*

polyethylene bags. The zoobenthos samples were taken from the entire cross-section of the stream using the standard hydrobiological methods (EN ISO 27828) and put to plastic sample enclosures filled with water. The chub (*Leuciscus cephalus*), typical omnivorous species populating all fish zones existing in rivers, the barbel (*Barbus barbus*), dominant representative of the fish fauna at both sites and the brown trout (*Salmo trutta* m. *fario*), which are most often caught (and eaten) by the anglers downstream of the above-specified reservoirs, were chosen as the ichthyoindicators. The sampled fish were caught using the standard method of electro-fishing, and the fish muscle analyses relied on samples taken from 7 individuals of each species. Fish were put to chill boxes and carried to the laboratory for further processing. Samples of the muscle tissue to be analysed were taken individually from the left dorsal part of fish body (without skin). To determine the age of fish by the scale-metric method, 5 to 10 scales were taken from each specimen. All samples were immediately frozen and kept at temperature –18 °C. Analyses of the contents of heavy metals were realized in the Department of Chemistry and Biochemistry (Mendel university in Brno). The content of total Hg was analysed by the direct method, using the AMA 254 device (Altec, Prague) with a detection limit of Hg 0.001 µg/kg, more detailed described in Houserová *et al.* (2006a). The concentrations of Cd, Cu, Cr, Zn, Ni & Pb were analysed after a wet way mineralising of the samples in the microwave oven ETHOS SEL (Milestone) by the flame AAS method, using the SPECTR AA-30 (detection limits: Cd 0.005 µg/kg, Pb 0.100 µg/kg, Cr 0.020 µg/kg, Ni 0.080 µg/kg) and AA-300 devices (detection limits: Cu 2.0 µg/kg, Zn 10.0 µg/kg). The analyses were performed with reliance on the NIST 1570a, BCR 414, NCR and DORM-2 standards (more detailed in Spurný *et al.*, 2002). The obtained data were entered into Microsoft Excel spreadsheets to be statistically evaluated using the Unistat 5.1 program. The ANOVA with post–hoc Tukey HSD test was performed ($P < 0.05$). The outputs were compared with EU regulation 221/2002/EC, Government Order no. 229/2007 Coll. and decree of Ministry of Health of Czech Republic No. 305/2004 Coll. and, moreover, with the limit of fish muscle consumption using WHO method (technical report series No. 837).

RESULTS AND DISCUSSION

Resulted contents of heavy metals in the water, bottom sediment and zoobenthos of the Jihlava River are presented in Table I. Having compared the limit values specified in the applicable legislation (EU regulation 221/2002/EC, Government of Czech Republic Decree 229/2007 Coll.), we found the above-limit content of mercury in the water (maximal permissible concentration 0.1 µg/l). The content at Vladislav (2.00 µg/l) was twice higher compared to Hrubšice (0.99 µg/l) and almost twice higher than value reported from the Vladislav site by Spurný *et al.* (2002), while at Hrubšice the Hg concentration was almost twice lower compared to the research realized by Spurný *et al.* (2009) in the similar site.

Concentrations of all analysed metals in bottom sediments were higher at Vladislav than at Hrubšice, except the amount of Ni, which was almost three times higher at Hrubšice. In comparison with Spurný *et al.* (2009) the content of Zn (53.93 mg/kg) and Cr (64.50 mg/kg) was markedly higher at Hrubšice (the authors reported the content of Zn 13.60 and Cr 18.99 mg/kg in wet matter in years 2001–2002). The contents of remaining metals were similar. Spurný *et al.* (2002) found similar content of Hg, Cd, Cu and Zn in sediment at Vladislav, the content of Pb (18.03 mg/kg) was seven times lower, Cr (15.44 mg/kg) ten times lower and Ni (6.39 mg/kg) five times lower compared to our sample. Houserová *et al.* (2006a) reported the concentration of Hg in sediments dry matter from Vladislav as high as 0.05–0.23 mg/kg. Spurný and Mareš (2005) confirmed similar concentration of Cu (2.60–10.53 mg/kg) and Zn (19.51–74.48 mg/kg), higher concentration of Hg (0.01–0.14 mg/kg) and lower concentrations of Pb (2.80–20.96 mg/kg), Cr (0.74–23.67 mg/kg) and Ni (0.89–20.23 mg/kg) in bottom sediments in the Bečva River. Vítek *et al.* (2007) found out similar concentrations of Zn (75.10 mg/kg) and Cd (0.30 mg/kg), lower concentrations of Pb (12.05 mg/kg), Cr (36.20 mg/kg) and Ni (24.98 mg/kg) and higher concentrations of Hg (0.21 mg/kg) and Cu (80.20 mg/kg) in sediments of the Loučka River. Increased content of analysed metals deposited within sediments in the Jihlava River represent some ecological risk of sudden release from sediments due to hydrological changes, namely pH fluctuation.

I: *Content of monitored polutants in water(µg/l), bottom sediment and bentos (mg/kg of wet matter)*

Sample	Sampling site	Hg	Zn	Cd	Pb	Ni	Cr	Cu
Water	Vladislav	2.00	0.03	0.00	0.40	6.40	0.83	0.00
	Hrubšice	0.99	0.02	0.02	0.40	7.00	1.54	0.00
Bottom sediment	Vladislav	0.04	110.05	0.27	120.21	32.06	164.90	14.71
	Hrubšice	0.02	53.93	0.12	3.46	90.66	64.50	7.99
Zoobenthos	Vladislav	0.02	38.68	0.20	25.84	1.90	3.05	6.37
	Hrubšice	0.01	76.89	0.18	0.82	0.24	0.14	8.08

When comparing our results of concentrations of metals in zoobenthos samples with the other authors, Spurný *et al.* (2009) reported similar concentration of Hg, Pb and Zn, higher amount of Cu (21.81 mg/kg) and Cd (0.57 mg/kg) and lower amount of Cr (2.79 mg/kg) and Ni (10.13 mg/kg) at Hrubšice. Spurný *et al.* (2002) found similar contents of analysed metals at Vladislav, but with exception of Pb, which content was lower (1.92 mg/kg) in their study. Houserová *et al.* (2006a) assessed Hg in zoobenthos dry matter from the same locality in the amount of 0.04–0.27 mg/kg (higher than in our study). Comparison of our zoobenthos samples with other rivers reveals similar contents of Zn, Cd and Cu, higher concentration of Hg (0.01–0.14 mg/kg), slightly lower amount of Cr (0.10–1.20 mg/kg) and Ni (0.06–1.81 mg/kg) and markedly lower concentration of Pb (0.28–3.79 mg/kg) in the Bečva River (study of Spurný and Mareš, 2005). In zoobenthos samples from the Loučka River monitored by Vítek *et al.* (2007) the content of metals was similar, except higher Cu contamination (2.93–74.30 mg/kg) and lower concentrations of Zn (0.56–1.51 mg/kg) and Ni (1.51 mg/kg).

Analysed contents of heavy metals in fish muscle tissue are summarized in the Table II. Statistically significant higher ($p < 0.05$) content of Hg was found in barbel and chub muscle from Vladislav (0.155 ± 0.012 mg/kg and 0.163 ± 0.064 mg/kg) in comparison with Hrubšice (0.073 ± 0.035 mg/kg and 0.095 ± 0.082 mg/kg). This corresponds with results reported by Spurný *et al.* (2002, 2009), Houserová *et al.* (2006a) and Peňáz *et al.* (2005). The similar situation was in the case of Cd in chub (concentration 0.062 ± 0.140 mg/kg at Vladislav and 0.006 ± 0.002 mg/kg at Hrubšice, whereas the content of Ni in barbel was statistically significantly higher at Hrubšice (0.109 ± 0.040 mg/kg) compared to Vladislav (0.050 ± 0.017 mg/kg). The last significant difference ($p < 0.05$) was found in Pb concentrations, when fish from Hrubšice were more contaminated (concentrations 0.155 ± 0.048 mg/kg in barbel and 0.182 ± 0.110 mg/kg in chub) than the same species from Vladislav (contents 0.108 ± 0.084 mg/kg and 0.064 ± 0.005 mg/kg). This higher Pb contamination downstream the Dalešice and Mohelno dam reservoirs do not correspond with contamination of the bottom sediments (storage and potential source) and zoobenthos (feeding grounds), which is relatively low in this area. It could be caused by negative impact of the nuclear power plant Dukovany. The comparison among species within sites showed statistically significant higher ($p < 0.05$) content of Zn in barbel (6.340 mg/kg) than in chub (5.194 mg/kg) at Vladislav and significantly higher content of Ni in chub (0.175 mg/kg) than in barbel (0.109 mg/kg) at Hrubšice. The statutory limits valid in the time of sampling were not exceeded. Peňáz *et al.* (1979) reported the concentration of Hg in the muscle tissue of barbel from Hrubšice in range from 0.140 to 0.220 mg/kg, twenty three years later this range decreased to 0.030–0.113 mg/kg (Peňáz *et al.* 2002). Houserová *et al.* (2006a) found out the content of Hg as high as 0.135 mg/kg in the same locality. Those values are similar to our observation (with exception of Peňáz *et al.*, 1979 higher maximal value of Hg concentration). At Vladislav site Spurný *et al.* (2002) found out similar concentration of the Hg (0.136 ± 0.032 mg/kg) in chub muscle, while higher amount (0.962 ± 0.450 mg/kg) was mentioned by Houserová *et al.* (2006a), Peňáz *et al.* (2005, 0.148–0.251 mg/kg) and Spurný and Mareš (1995, 0.15–0.43 mg/kg). Spurný and Mareš (2005) reported from the Bečva River concentration of Hg 0.074–0.107 mg/kg. When we compare concentration of Hg in fish muscle from the Jihlava River with the other Czech rivers, we can consider it as a relatively low. For example Svobodová *et al.* (1993) report Hg concentration 1.600 mg/kg in perch from Elbe River near Čelákovice, Žlábek *et al.* (2006) monitored Hg concentrations in chub muscle from the Elbe River near Svádov and from the Morava River near Litovel and found out mean contents 0.291 mg/kg and 0.214 mg/kg. In the brown trout muscle Svobodová *et al.* (2004) detected amount of Hg in range 0.410–1.631 from the Divoká Orlice River and Vítek *et al.* (2007) reported mean concentration in the Loučka River 0.390 mg/kg. In the case of the other analysed metals, we could compare our results from Jihlava River with Peňáz *et al.* (2005) and Spurný *et al.* (2009). The firstly mentioned authors reported similar amount of Cr (0.354 mg/kg); Cu (0.578 mg/kg); Zn (5.770 mg/kg) and Cd (0.028 mg/kg) in barbel muscle, lower amount of Pb (0.066 mg/kg) and higher amount of Ni (0.240 mg/kg), the second collective found similar concentration of Cu (0.640 mg/kg); Zn (5.310 mg/kg) and Cd (0.010 mg/kg); higher concentration of Ni (0.062 mg/kg); Cr (0.046 mg/kg) and

II: *Content of monitored polutants in fish muscle (mg/kg of wet matter)*

Species	Sampling sites	Age	Hg	Zn	Cd	Pb	Ni	Cr	Cu
B. barbus	Vladislav	6–9	0.155 ± 0.012 **x**	6.340 ± 1.100 **a**	0.037 ± 0.007	0.108 ± 0.084 **x**	0.050 ± 0.017 **x**	0.044 ± 0.017	0.446 ± 0.008
	Hrubšice	5–9	0.073±0.035 **y**	5.316 ± 1.160	0.017 ± 0.017	0.155 ± 0.048 **y**	0.109 ± 0.040 **a**,**y**	0.583 ± 0.533	0.664 ± 0.370
L. cephalus	Vladislav	6–8	0.163 ± 0.064 **x**	5.194 ± 0.500 **b**	0.062 ± 0.140 **x**	0.064 ± 0.005 **x**	0.011± 0.190	0.022 ± 0.023	0.495 ± 0.620
	Hrubšice	6–18	0.095 ± 0.082 **y**	5.831 ± 1.640	0.006 ± 0.002 **y**	0.182 ± 0.110 **y**	0.175 ± 0.042 **b**	0.040 ± 0.013	0.384 ± 0.160
S. trutta m. *fario*	Hrubšice	2–6	0.055 ± 0.059	5.960 ± 2.470	0.012 ± 0.004	0.158 ± 0.077	0.125 ± 0.060	0.060 ± 0.042	0.510 ± 0.200

a, **b** letters mark statistically different values among species on individual sites, $p < 0.05$
x, **y** letters mark statistically different values between sites, $p < 0.05$

III: *Maximal fish muscle intake from middle course of the Jihlava River according to FAO/WHO limits (in kg per 60 kg person)*

Species \ Limits (µg/kg)	Sampling site \ Metal	Hg	Zn	Cd	Pb	Cu
		5 PTWI	1000 PMTDI	7 PTWI	25 PTWI	500 PMTDI
Barbus barbus	Vladislav	1.94	9.43	4.69	13.85	67.27
	Hrubšice	4.12	11.29	10.60	9.65	4.52
Leuciscus cephalus	Vladislav	1.84	11.55	6.75	23.33	118.90
	Hrubšice	3.15	10.29	66.66	8.32	45.05
Salmo trutta m. *fario*	Hrubšice	5.51	10.07	35.38	9.47	58.82

PTWI – provisional tolerable weekly intake
PMTDI – provisional maximum tolerable daily intake

markedly higher concentration of Pb (0.768 mg/kg) in chub muscle.

Compared to the other rivers, Vítek *et al.* (2007) reported the similar concentrations of Cr, Cu and Zn and higher amount of Pb in brown trout muscle from the Loučka River and Svobodová *et al.* (2004) found also similar content of Cr, Cu and Zn in brown trout from the Tichá Orlice River. Spurný and Mareš (2005) found similar concentration of Cd; Pb; Cr; Zn and Ni in chub muscle from the Bečva River, the chubs from Elbe River were slightly low contamined by Cd and Pb (Žlábek *et al.*, 2006). According to the comparisons the fish from Jihlava River seems to be similarly contamined by monitored metals.

Table III. informs about maximum tolerable human intake of fish muscle from the Jihlava River, according to the actually valid FAO/WHO recommendation. It is obvious, that the limiting metal is Hg. The lowest tolerable intake was found in chub and in barbel from Vladislav locality (PTWI 1.84 kg and 1.94 kg). In the research realized by Spurný *et al.* (2009) was found slightly lower health risk (PTWI 2.00 kg of chub limited by Pb contamination, due to Hg residuals the tolerated intake was 2.30 kg) The Hrubšice locality constitutes lower risk with tolerable intake 3.15 kg of chub muscle caused by Hg contamination. With regard to quantity of anglers catch from this river (in average 90 individuals of chub with weight 76.30 kg in total and 35 specimen of barbel weighing 51.90 kg per year) the risk of human intake of fish is relatively low nowadays, but with expectation of increasing angling pressure it could be important in future. Comparing the brown trout (dominates in anglers catch) consumption health risk with Vítek *et al.* (2007) study of the Loučka River, it is markedly lower. We have found out tolerable intake 5.51 kg due to increased content of Hg at Hrubšice; whereas they confirmed high contamination by Pb limiting the consumption up to 1.50 kg per week (Hg contamination allows consumption of 2.80 kg).

CONCLUSION

Analyses of residual contamination of the Jihlava River water courses environment confirmed the excess of Czech Republic legislation limit for mercury in water at both sites of interest (Hrubšice and Vladislav). In the point of view bottom sediments and zoobenthos contamination there is no mandatory limit of trace metals, but in comparison with the other South Moravian watercourses we can consider them as a quite high. This high contamination, however, was not reflected in increased concentrations of the metals in the muscle tissue of fish. The contents of Hg and Cd were demostrably higher at Vladislav than at Hrubšice sampling site. This fact confirms the presumed retention effect of the Dalešice and Mohelno waterworks on the pollutants, first and foremost the mercury, and thus on the overall quality of the Jihlava River environment downstream of the reservoirs. The muscle tissue of fish assessed for the safety of human consumption was found as a low risky at Hrubšice while the health hazard exists at Vladislav site for reasons attributable to the high content of mercury in the muscle tissue of fish caught there.

SUMMARY

The fish muscle tissue contamination by heavy metals represents a potential risk for human health. Especially the mercury, lead and cadmium in fish body from rivers, which flow through industrial grounds, are very often in high concentration. That is the case of the Jihlava River flowing through towns Jihlava and Třebíč. This river was often referred to as strongly polluted by heavy metals in the past. Especially the mercury was reported in high concentrations, mainly upstream the Dalešice and Mohelno reservoirs, below the town Třebíč.

This paper aims to assess the contents of heavy-metal residues in the fish muscle tissue in the mentioned river and to compare the contents of such residues found to contaminate the muscle tissue of

fish living upstream and downstream of the Dalešice and Mohelno dam reservoirs; and to evaluate the consumption safety of fish caught by anglers at these sites. Additionally, the content of heavy metals in water, bottom sediments and zoobenthos samples of the Jihlava River was analysed.
The research was focused on following metals: total Hg, Pb, Cd, Cu, Cr, Zn and Ni. Samples of the water, bottom sediments, zoobenthos and muscle tissue of chub (*Leuciscus cephalus*), barbel (*Barbus barbus*) and brown trout (*Salmo trutta* m. *fario*) to be analysed for their contents of heavy metals were collected during the growing season of 2007 from two sites (site Vladislav located upstream the Dalešice and Mohelno reservoirs and site Hrubšice downstream them). Fish were caught using the standard method of electro-fishing, and muscle tissue (without skin) was taken individually (7 representatives of each species from each locality) from the left dorsal part of fish body. Concentrations of metals were assessed using the AMA 254, SPECTR AA-30 and AA-300 devices. Data were statistically evaluated using the Unistat 5.1 (ANOVA with post–hoc Tukey HSD test, $p < 0.05$). The outputs were compared with EU regulation 221/2002/EC and with the WHO recommended consumption limit (technical report series No. 837).
We found above-limit content of mercury in the water (maximal permissible concentration 0.1 µg/l). The content at Vladislav (2.00 µg/l) was twice higher then the concentration at Hrubšice (0.99 µg/l). The amount of Ni was higher in bottom sediment on the Hrubšice site than the Vladislav site. The amount of Zn, Cd, Pb and Cr was higher on the Vladislav site, the amount of Hg and Cu was similar on the both localities. In general, the amount of the heavy metals was very high in bottom sediment. Increased content of trace metals deposited within sediments in the Jihlava River represent some ecological risk of sudden release from sediment due to hydrological changes, namely pH fluctuation.
In the point of view contents of heavy metals in fish muscle tissue, statistically significant higher content of Hg was found in barbel and chub from Vladislav (0.155 ± 0.012 mg/kg and 0.163 ± 0.064 mg/kg) in comparison with Hrubšice (0.073 ± 0.035 mg/kg and 0.095 ± 0.082 mg/kg). The similar situation was in the case of Cd in chub (concentration 0.062 ± 0.140 mg/kg at Vladislav and 0.006 ± 0.002 mg/kg at Hrubšice), whereas the content of Ni in barbel was statistically significantly higher at Hrubšice (0.175 ± 0.042 mg/kg) compared to Vladislav (0.050 ± 0.017 mg/kg). The last significant difference was found in Pb concentrations, when fish from Hrubšice were more contaminated (concentrations 0.155 ± 0.048 mg/kg in barbel and 0.182 ± 0.110 mg/kg in chub) than the same species from Vladislav (contents 0.050 ± 0.017 mg/kg and 0.064 ± 0.005 mg/kg). This higher fish muscle contamination by Pb downstream the Dalešice and Mohelno dam reservoirs do not reflect the concentrations of this metal in the bottom sediment and zoobenthos, which is relatively low in this area in comparison with locality upstream the reservoirs. The comparison among species within sites showed statistically significant higher content of Zn in barbel (6.340 mg/kg) than in chub (5.194 mg/kg) at Vladislav and significantly higher content of Ni in chub (0.175 mg/kg) than in barbel (0.109 mg/kg) at Hrubšice. The statutory limits valid in the time of sampling were not exceeded.
From computed tolerable human intake of fish muscle according to the actually valid FAO/WHO recommendation, it is obvious, that the limiting metal is Hg. The lowest provisional tolerable weekly intake (PTWI) was found in chub and in barbel from Vladislav locality (1.84 kg and 1.94 kg). With regard to quantity of anglers catch from monitored river the risk of human intake of fish is relatively low nowadays, but with expectation of increasing angling pressure it could be important in future.

SOUHRN

Zatížení ekosystému středního toku řeky Jihlavy těžkými kovy

Kontaminace svaloviny ryb těžkými kovy představuje potenciální riziko pro konzumenty ryb. Řeky protékající územím s velkými aglomeracemi a silným průmyslovým využitím bývají často velmi zatížené, zvláště rtutí, olovem a kadmiem. Řeka Jihlava protéká několika městy s výraznou průmyslovou aktivitou, například Jihlavou a Třebíčí. Tato řeka bývala v minulosti často označována jako silně znečištěná, nejvíce rtutí v úseku nad vodními díly Dalešice a Mohelno.
Cílem tohoto sledování bylo zjištění obsahu těžkých kovů ve svalovině ryb žijících nad a pod vodními díly Dalešice a Mohelno a posouzení vlivu těchto vodních děl na úroveň kontaminace ryb. Pro upřesnění situace na toku byl zjišťován obsah těžkých kovů ve vodě, sedimentu dna a zoobentosu na obou lokalitách.
Monitoring byl zaměřen na tyto kovy: Hg, Pb, Cd, Cu, Cr, Ni a Zn. Vzorky vody, sedimentu dna, zoobentosu a rybí svaloviny byly odebrány v průběhu roku 2007 ze dvou lokalit řeky Jihlavy: Vladislav (odběr 15. srpna) nad vodními díly Dalešice a Mohelno, nedaleko města Třebíč a Hrubšice (odběr 25. května) pod vodními nádržemi. Vzorky vody byly odebrány do 1,5 l polyetylenových lahví. Vzorky sedimentu dna a zoobentosu byly odebrány jako směsné vzorky napříč lokalitami, dle standardních metodik (EN ISO 27828). Jako ichtyoindikátor byla zvolena parma obecná (*Barbus barbus*), jelec tloušť (*Leuciscus cephalus*) a pstruh obecný (*Salmo trutta* m. *fario*). Vzorky ryb byly získány za použití standard-

ních metod odlovu elektrickým agregátem, sedm jedinců od každého sledovaného druhu ryb. Svalovina ryb byla odebírána individuálně z levé hřbetní části trupu každé ryby bez kůže. Obsah sledovaných kovů byl stanoven na Ústavu chemie a biochemie Mendelovy univerzity v Brně za použití přístrojů AMA 254, SPECTR AA-30 a AA-300. Zjištěné výsledky byly statisticky vyhodnoceny v programu Unistat 5.1 metodami ANOVA a Tukey HSD ($P < 0,05$). Získané výsledky byly porovnány se směrnicí EU 221/2002/EC, množství bezpečně konzumovatelné svaloviny ryb bylo vypočítáno za užití metodiky WHO (směrnice č. 837).

Při porovnání zjištěných koncentrací jednotlivých kovů s platnou legislativou (směrnice 2005/78/EC, nařízení vlády č. 229/2007 Sb., a vyhláška č. 305/2004 Sb.) jsme nalezli překročený limit pro obsah rtuti ve vodě (limit 0.1 µg/l). Dále jsme zjistili, že obsah rtuti ve vodě na lokalitě Vladislav (2.00 µg/l) byl dvakrát vyšší než na lokalitě Hrubšice (0.99 µg/l). V sedimentu dna na lokalitě Hrubšice byl zjištěn vyšší obsah niklu než na lokalitě Vladislav, kde bylo naopak vyšší množství kadmia, olova, chromu a niklu. Obsah rtuti byl na obou lokalitách podobný. Velmi vysoký obsah těžkých kovů v sedimentu znamená potenciální nebezpečí s ohledem na nenadálé uvolnění během náhlých změn chemismu vody, zejména pH.

Z hlediska obsahu jednotlivých kovů v rybí svalovině byly zjištěny následující skutečnosti. Na lokalitě Vladislav byl nalezen ve svalovině parmy i tlouště statisticky průkazně vyšší obsah Hg (0,155 ± 0,012 mg/kg a 0,163 ± 0,064 mg/kg) oproti lokalitě Hrubšice (0,073 ± 0,035 mg/kg a 0,095 ± 0,082 mg/kg). Podobná situace byla i v případě kadmia u jelce tlouště (0,062 ± 0,140 mg/kg ve Vladislavi a 0,006 ± 0,002 mg/kg v Hrubšicích), naopak na lokalitě Hrubšice byl u parmy zjištěn statisticky průkazně vyšší obsah Ni (0,109 ± 0,040 mg/kg) oproti Vladislavi (0,050 ± 0,017 mg/kg). Dále byl u parmy i jelce tlouště zjištěn statisticky vyšší obsah olova na lokalitě Hrubšice (0,155 ± 0,048 mg/kg u parmy a 0,182 ± 0,110 mg/kg u tlouště) než na lokalitě Vladislav (0,050 ± 0,017 mg/kg a 0,064 ± 0,005 mg/kg). Vyšší obsah olova ve svalovině ryb pod přehradními nádržemi Dalešice a Mohelno nekoresponduje s koncentracemi tohoto kovu v sedimentu dna a následně i v zoobentosu, jež jsou v této oblasti relativně nízké ve srovnání s lokalitou nad nádržemi.

Výpočet maximálních tolerovaných množství zkonzumované svaloviny ryb dle platných předpisů FAO/WHO odhalil, že na obou lokalitách byla limitujícím prvkem rtuť. Nejnižší tolerované množství bylo nalezeno v případě jelce tlouště a parmy obecné na lokalitě Vladislav (1,94 kg a 1,84 kg na osobu týdně). V současné době, s ohledem na množství lovených ryb v tomto revíru (v průměru 90 kusů jelce tlouště o celkové hmotnosti 76,30 kg a 35 kusů parmy obecné s celkovou hmotností 51,90 kg ročně) lze konzumaci rybí svaloviny z těchto lokalit považovat za relativně bezpečnou, v souvislosti se vzrůstajícím rybářským tlakem však může do budoucna znamenat určité riziko.

parma obecná (*Barbus barbus*), jelec tloušť (*Leuciscus cephalus*), pstruh obecný (*Salmo trutta*), kontaminace kovy

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REFERENCES

BURGER, J., GAINES, K. F., BORING, C. S., STEPHENS, W. L., SNADGRASS, J., DIXON, C., MCMAHON, M., SHUKLA, S., SHUKLA, T., GOFELD, M., 2002: Metal levels in fish from the Savannah Riwer: potential hazards to fish and other receptors. *Environ. Res.* 89, 1: 85–97. ISSN 0013-9351.

DECREE of Ministry of health of Czech Republic No. 305/2004 Coll. Types and admissible values of contaminants in foodstuff. *Collection of law Czech Republic.*

EN (ISO) 27 828 Water quality: Methods of biological sampling Guidance on handnet sampling of aquatic benthic macro-invertebrates (ISO 7828:1985).

EU Regulation 221/2002/EC amending Regulation 466/2001/EC setting maximum levels for certain contaminants in foodstuff.

GOVERNMENT ORDER No. 229/2007 Coll. Amending government order No. 229/2007 Coll. On the indicators and values of permissible pollution of surface water and wastewater, mandatory element of the permis for discharge of wastewater into surface water and into sewerage system, and on sensitive areas. *Collection of law Czech Republic.*

HOUSEROVÁ, P., JANÁK, K., KUBÁŇ, P., PAVLÍČKOVÁ, J., KUBÁŇ, V., 2006b: Chemical Forms of Mercury in Aquatic Ecosystems – Sources, Levels, Transformations, Properties and Determination. *Chemické listy*, 100, 10: 862–876. ISSN 0009-277.

HOUSEROVÁ, P., KUBÁŇ, V., SPURNÝ, P., HABARTA, P., 2006a: Determination of Total Mercury and Mercury Species in Fish and Aquatic Ecosystem of Moravian Rivers. *Veterinarni medicina*, 51, 3: 101–110. ISSN 0375-8427.

LANGE, T. R., ROYALS, H. E., CONNOR, L. L., 1993: Influence of water chemistry on mercury concentration in Largemouth bases from Florida. *Transactions of the American Fisheries Society*. 122, 1: 74–84. ISSN 0002-8487.

PEŇÁZ, M., BARUŠ, V., PROKEŠ, M., 2002: Concentration of heavy metals and changes in concentrations of the mercury in muscle tissues of the barbel (*Barbus barbus*) from the river Jihlava (in Czech with English summary). *The 5th Czech conference of Ichthyology.* Brno, 253–258. ISBN80-7157-614-X.

PEŇÁZ, M., SVOBODOVÁ, Z., BARUŠ, V., PROKEŠ, M., DRASTICHOVÁ, J., 2005: Endocrine disruption in a barbel, *Barbus barbus* population from the River Jihlava, Czech Republic. *Journal of Applied Ichthyology*, 21, 5: 420–428. ISSN 0175-8659.

PEŇÁZ, M., SVOBODOVÁ, Z., HEJTMÁNEK, M., TRNKOVÁ, J., 1979: Mercury contents in muscles of fishes from the Jihlava River. *Folia Zoologica*. 28, 171–176.

SAGER, D. R., 2002: Long-term variation in mercury concentration in estmarine organismes with changes in releases into Lavaca Bay, Texas. *Pollut Bull*., 44, 8: 807–815. ISSN 0025-326X.

SPURNÝ, P., MAREŠ, J., 1995: Distribuce těžkých kovů v rybách řeky Dyje. In: *Toxicita a biodegradabilita odpadů a látek významných ve vodním prostředí*. Milenovice, 75–79.

SPURNÝ, P., MAREŠ, J., 2005: Kontaminace ekosystému řeky Bečvy na Přerovsku vybranými těžkými kovy. In: VYKUSOVÁ, B., 2005: *Toxicita a biodegradabilita odpadů a látek významných ve vodním prostředí*. 1: 122–126. ISBN 80-85887-55-X.

SPURNÝ, P., MAREŠ, J., HEDBÁVNÝ, J., SUKOP, I., 2002: Heavy metal distribution in the ecosystems of the upper course of the Jihlava River. *Czech Journal of Animal Science*. 47, 4: 160–167. ISSN 1212-1819.

SPURNÝ, P., MAREŠ, J., HEDBÁVNÝ, J., SUKOP, I., 2009: Residual Metal Contamination of the Ecosystem in the Lower Course of the Jihlava River. *Acta Veterinaria Brno*. 78, 3: 525–534. ISSN 0001-7213.

SUMMARY of Evaluations Performed by the Joint FAO/WHO Expert comittee on Food Additives (JECFA 1956–2005). ILSI Press Washington, 2006

SVOBODOVÁ, Z., ČELECHOVSKÁ, O., ŽLÁBEK, V., 2004: Assesment of metal contamination in the upper reaches of the Tichá Orlice River. *Czech Journal of Animal Sciences*. 49, 10: 458–464. ISSN 1212-1819.

SVOBODOVÁ, Z., VYKUSOVÁ, B., MÁCHOVÁ, J., BASTL, J., HRBKOVÁ, M., SVOBODNÍK, J., 1993: Pollutants monitoring in fish of the Labe River on the Čelákovice locality (in Czech with English summary). *Bull. of Research Institute of Fishery and Hydrobiology Vodňany*, 47–61.

VÍTEK, T., SPURNÝ, P., MAREŠ, J., ZIKOVÁ, A., 2007: Heavy metal contamination of the Loučka Riwer water ecosystem. *Acta Veterinaria Brno.* 76, 1: 149–154. ISSN 0001-7213.

WHO TECHNICAL REPORT SERIES NO. 837: Evaluation of certain food additives and contaminants. *Thirty-third report of the Joint FAO/WHO expert commitee of food additives Geneva.*

ŽLÁBEK, V., RANDÁK, T., SVOBODOVÁ, Z., MÁCHOVÁ, J., KOLÁŘOVÁ, J., VALENTOVÁ, O., ČELECHOVSKÁ, O., MARŠÁLEK, P., HAJŠLOVÁ, J., ROSMUS, J. DUŠEK, L., 2006: Hygienic quality of fish in the Czech Republic. *23th World Congress of Czechoslovak Society of Art and Sciences*. České Budějovice, 150–151.

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