Mercury content in the muscle of fish from the Elbe River and its tributaries

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ABSTRACT: The main aim of the present study was to assess the mercury contamination of the Elbe River and its tributary the Vltava River. Mercury concentrations in fresh fish muscles were used for the contamination assessment. The samples were collected in 1999, 2002 and 2003 at 7, 2 and 1 collection sites from the Elbe River, Vltava River and Blanice River (tributary of the Vltava River), respectively. Samples of bream (*Abramis brama* L.), perch (*Perca fluviatilis* L.) and chub (*Leuciscus cephalus* L.) muscle were collected at the monitored sites. A single-purpose mercury analyser AMA 254 was used to determine the total mercury content in the muscle tissue of fish. Average concentrations of mercury in the muscle of bream, perch and chub were in the range 0.172–0.852 mg/kg, 0.077–1.07 mg/kg and 0.141–1.631 mg/kg, respectively. The highest values of total mercury content were found in fish from the localities Obříství and Lysá nad Labem ($P < 0.05$; $P < 0.01$, respectively) in the river section from 120th to 160th river kilometre. The highest value of total mercury content (2.56 mg/kg) in the fresh muscle of chub was in the Obříství vicinity. It poses a high risk for consumers, considering the average consumption of 10 kg fish per capita/year (hazard index 3.0). On the other hand, total mercury contamination decreased in the localities Děčín and Hřensko (15th–5th r. km) in the period 1999–2003. The findings in 2003 indicated that the disastrous floods in 2002 did not significantly influence the mercury contamination of fish.

Keywords: Vltava River; *Abramis brama* L.; *Perca fluviatilis* L.; *Leuciscus cephalus* L.

The Elbe River is one of the most important European rivers (total length 1 103.5 kilometres). Its wide drainage basin traverses the territory of two countries (in total 148 268 km^2, Czech Republic – 51 336 km^2, Germany – 96 932 km^2). Intensive investigations of the Elbe River pollution in the Czech Republic and also in Germany were initiated in 1991 in the framework of projects Elbe I (1991–1994), Elbe II (1995–1998) and Elbe III (1999–2002). Under these projects data on a variety of pollution sources were collected and evaluated: chemical monitoring of harmful substances, water quality, etc. (Nesměrák, 1994; Blažková at al., 1998; Blažková, 2002; Čelechovská et al., 2005; Široká et al., 2005). To improve the results of obtained by chemical monitoring it is necessary to include the influence of anthropogenic pollution in the aquatic environment and any impacts it might have on the fish.

In the study area of the Elbe River and its tributary the Vltava River, the main indicator species are bream (*Abramis brama* L.), perch (*Perca fluviatilis* L.) and chub (*Leuciscus cephalus* L.). The present paper gives the results of a study of mercury content in the muscle tissue of fish collected at eight and/or nine sites of the Elbe River and its tributary. The aims of the study were to measure contamination levels at individual collection sites and to compare

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Figure 1. Map of the Czech Republic and location of sampling sites in the present study

mercury contents in the muscle tissue of different fishes with public health standards, and thus to help implement a variety of food safety strategies.

MATERIAL AND METHODS

Indicator fish (*Abramis brama* L., *Perca fluviatilis* L.) were collected at sites along the Elbe River and its tributary (Vltava River) in 1999, 2002 (before floods) and in 2003. Chub (*Leuciscus cephalus* L.) was sampled in 2003 only. The main characteristics of sampled bream, perch and chub are given in Table 1, 2 and 3, respectively. The collection sites of the Elbe River were Verdek (313th river km), Němčice (256th r. km), Valy (224th r. km), Lysá nad Labem (160th r. km), Obříství (116th r. km), Děčín (21st r. km) and Hřensko (2nd r. km). The collection sites of the Vltava River were Podolí (165th r. km) and Zelčín (113th r. km), (Figure 1). A locality on the Blanice River upstream from the water reservoir Husinec was used as a control locality for the mercury content in chub. The fish were collected after they were stunned with an electric generator set.

Table 1. The main characteristics (mean ± SD) of sampled bream (*Abramis brama* L.)

Locality	1999			2002			2003		
	n	body mass (g)	age (years)	*n*	body mass (g)	age (years)	*n*	body mass (g)	age (years)
Podolí	1	900	10	–	–	–	5	510 ± 60.4	6.6 ± 0.55
Zelčín	2	315 ± 275.8	4.0 ± 2.83	5	449 ± 73.7	5.6 ± 0.89	5	997 ± 104.9	4.6 ± 0.55
Verdek	–	–	–	–	–	–	–	–	–
Němčice	9	186 ± 70.5	2.1 ± 0.33	–	–	–	3	442 ± 23.6	5.7 ± 0.58
Valy	2	576 ± 741.0	3.5 ± 3.54	–	–	–	1	1 045	6
Lysá nad Labem	5	224 ± 64.8	3.6 ± 1.14	6	427 ± 66.5	6.0 ± 0.63	2	368 ± 222.7	4.5 ± 2.12
Obříství	2	535 ± 91.9	4.5 ± 0.71	2	545 ± 148.5	6.0 ± 0.00	2	725 ± 198.0	7.0 ± 1.41
Děčín	25	454 ± 331.1	3.7 ± 1.55	5	620 ± 280.0	5.4 ± 0.89	5	556 ± 269.2	4.4 ± 1.14
Hřensko	3	787 ± 202.6	7.0 ± 1.00	5	745 ± 104.6	6.6 ± 0.55	3	643 ± 320.6	6.0 ± 1.73

n = number of fishes examined

The caught fish were immediately weighed, their age was determined from their scales, and muscle tissue samples were taken for mercury content assessment. The sex of the fish was determined macroscopically and checked by the histological examination of gonads. The main characteristics of fish species examined in this study are summarized in Table 1. Muscle tissue samples were put into polyethylene bags, labelled and stored in a freezer at –18°C.

Muscle samples of individual bream, perch and chub were analysed for the content of mercury. The total mercury content in fish muscle tissues was determined by the AAS method using a single-purpose mercury analyser AMA-254 (ALTEC Ltd., CZ). The accuracy of the results was validated by the following standard reference materials: CRM No. 278 (mussel tissue of *Mytilus edulis* – BCR); MA-B-3/(TM) (fish homogenate – IAEA).

Results were tested using ANOVA in Statgraphics software, Unistat 5.1 and MS-EXCEL 7.0.

RESULTS

In the first part of the evaluation, metal concentrations were measured in muscle tissues of female and male fish from respective sites of the Elbe River and its tributary Vltava River. Data from the years 1999, 2002 and 2003 were compared. Because no significant sex-related differences in metal concentrations in muscle tissues were found, all fish from individual sites were used in further evaluations irrespective of their sex. An overview of mercury concentrations in muscle tissues of bream (*Abramis brama* L.), perch (*Perca fluviatilis* L.) and chub (*Leuciscus cephalus* L.) from the collection sites is in Figure 2, 3 and 4, respectively.

In all periods of observation, the highest values of total mercury content in the muscle of bream (*Abramis brama* L.) were found in Lysá nad Labem and Obříství localities. The analysis of variance proved a significantly higher mercury load in the muscle of bream from Obříství compared with the localities Podolí, Němčice, Děčín ($P < 0.01$), Zelčín and Hřensko ($P < 0.05$). Furthermore, higher levels of mercury in the fish muscle from Lysá nad Labem locality were proved in comparison with Podolí locality ($P < 0.05$). The influence of disastrous floods in August 2002 on the mercury load in monitored localities could not be proved. No significant variation was found in total mercury content in the muscle of bream in 1999 and 2002 (before floods) in comparison with the year 2003 in localities Zelčín, Lysá nad Labem, Obříství, Děčín and Hřensko.

The highest levels of total mercury content in the muscle of perch (*Perca fluviatilis* L.) were found out in Obříství and Lysá nad Labem localities in 1999 and 2002. In comparison with the other monitored localities this difference was significant ($P < 0.01$) and ($P < 0.05$), respectively. The highest levels in 2003 were found out in Verdek locality. The analysis of various sites proved higher concentrations of mercury in fish from Verdek compared with fish from sites at Podolí ($P < 0.01$) and Zelčín ($P < 0.05$). At these particular sites the total mercury content in perch muscle was also comparable for the assessed periods. The exceptions were Valy and Lysá nad

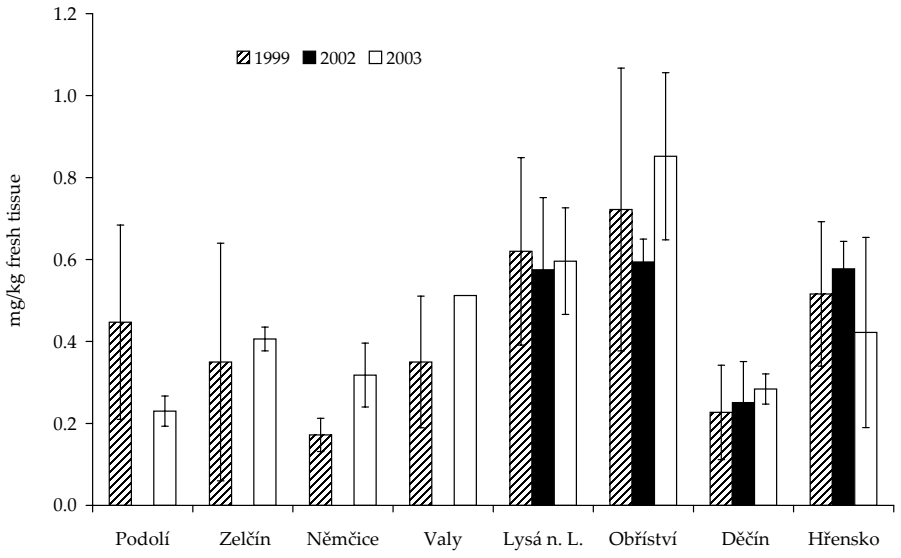

Figure 2. Comparison of mercury content in the muscle of bream (*Abramis brama* L.) from monitored sites of the Elbe River and its tributary

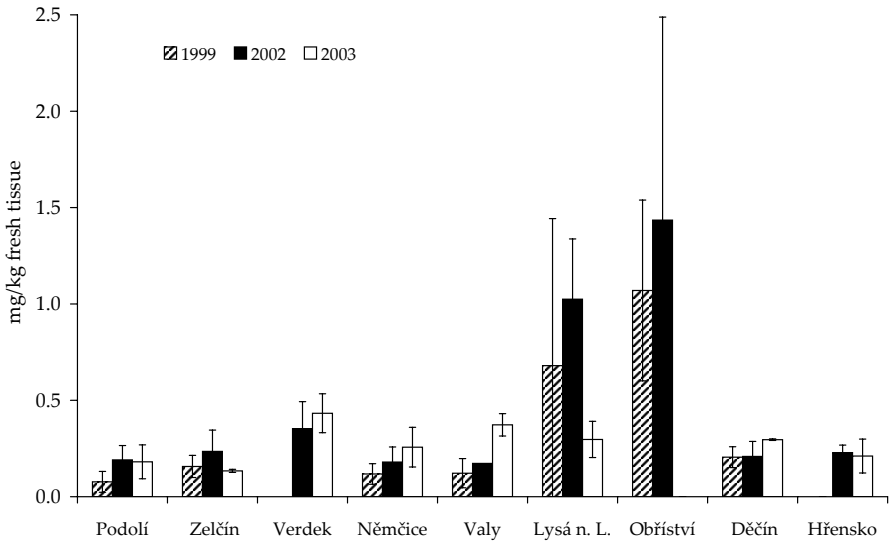

Figure 3. Comparison of mercury content in the muscle of perch (*Perca fluviatilis* L.) from monitored sites of the Elbe River and its tributary

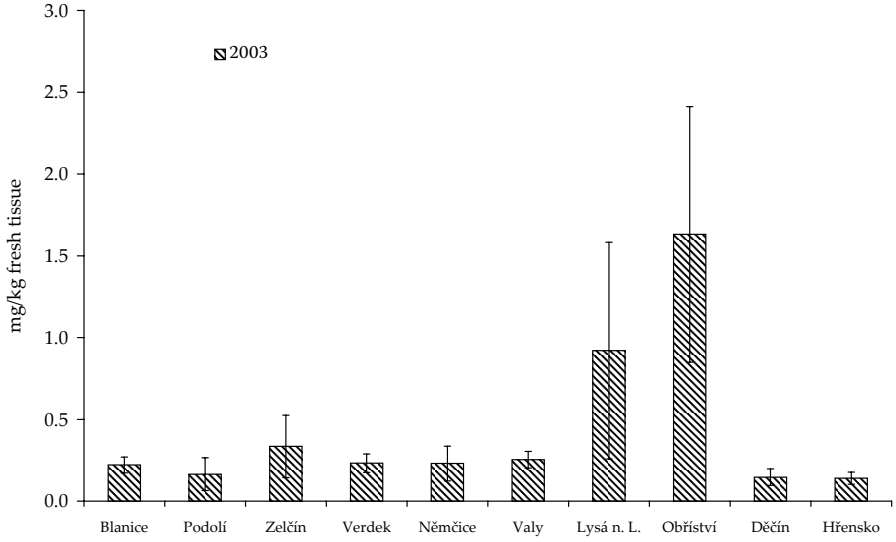

Figure 4. Comparison of mercury content in the muscle of chub (*Leuciscus cephalus* L.) from monitored sites of the Elbe River and its tributaries

Table 2. The main characteristics (mean ± SD) of sampled perch (*Perca fluviatilis* L.)

Locality	1999			2002			2003		
	n	body mass (g)	age (years)	*n*	body mass (g)	age (years)	*n*	body mass (g)	age (years)
Podolí	14	62 ± 46.3	1.5 ± 0.76	7	67 ± 16,8	4.0 ± 0.82	5	100 ± 28.5	3.4 ± 0.55
Zelčín	7	51 ± 15.6	1.6 ± 0.53	8	116 ± 29.8	4.3 ± 1.04	2	58 ± 10.6	3.5 ± 0.71
Verdek	–	–	–	3	67 ± 16.8	3.3 ± 0.58	7	118 ± 22.9	3.9 ± 0.69
Němčice	13	39 ± 18.0	1.6 ± 0.51	7	96 ± 65.0	4.0 ± 1.00	5	183 ± 131.4	4.8 ± 1.48
Valy	2	50 ± 17.7	2.0 ± 0.00	1	160	3	4	85 ± 43.6	4.0 ± 0.82
Lysá nad Labem	12	80 ± 130.8	1.7 ± 1.23	5	220 ± 148.8	4.4 ± 0.55	3	90 ± 31.2	3.7 ± 0.58
Obříství	5	175 ± 60.4	2.6 ± 0.89	6	318 ± 224.4	5.2 ± 1.94	–	–	–
Děčín	4	116 ± 24.3	2.0 ± 0.00	6	103 ± 24.8	3.5 ± 0.55	2	155 ± 42.4	4.5 ± 0.71
Hřensko	–	–	–	5	119 ± 15.2	3.2 ± 0.45	2	115 ± 63.6	2.5 ± 0.71

n = number of fishes examined

Table 3. The main characteristics (mean ± SD) of sampled chub (*Leuciscus cephalus* L.) in 2003

Locality	*n*	Body mass (g)	Age (years)
Husinec	6	218 ± 57.1	3.5 ± 0.55
Podolí	5	266 ± 100.6	4.0 ± 0.71
Zelčín	5	775 ± 392.2	6.2 ± 1.79
Verdek	5	372 ± 139.0	4.0 ± 0.71
Němčice	5	737 ± 359.7	6.6 ± 1.14
Valy	10	315 ± 90.0	3.4 ± 0.52
Lysá nad Labem	3	375 ± 297.2	4.3 ± 1.53
Obříství	8	893 ± 403.5	7.1 ± 1.89
Děčín	5	672 ± 196.8	6.6 ± 0.55
Hřensko	5	435 ± 159.5	4.6 ± 0.89

n = number of fishes examined

Labem localities. A significant increase of mercury concentration in perch muscle was found in Valy locality ($P < 0.05$) and a significant decrease ($P < 0.01$) was proved in Lysá nad Labem locality in 2003.

Total mercury content in the muscle of chub (*Leuciscus cephalus* L.) was measured only in 2003. The highest values were found out in chub from Obříství and Lysá nad Labem localities. Mercury concentrations in chub muscle were comparable in all other studied localities and significantly ($P < 0.01$) lower than those in Obříství and Lysá nad Labem localities.

DISCUSSION

In the framework of projects Elbe I, II and III (Nesměrák, 1994; Blažková et al., 1998; Blažková, 2002) bream (representative of non-predatory species) and perch (representative of predators) were used as indicator fish species in the territory of the Czech Republic and Germany. The availability and abundance of these species in monitored localities were not entirely regular and sufficient as evident from Table 1 and 2. The spectrum of indicator fish species has extended in the framework of project Elbe IV (2003–2007). The chub (*Leuciscus cephalus* L.) has become a normative species for the monitoring of aquatic pollution. It is evident from Table 3 that chub was present and abundant in all studied localities, which allowed selection of individuals of comparable weights. In addition, mercury content measured in the muscle of chub is comparable with the levels ordinarily found in perch as a predator fish. Chub is an omnivorous and insatiable fish species. With increasing body mass its voracity rises consuming higher numbers of smaller fish (Baruš, Oliva et al., 1995). This particular characteristic causes higher accumulations of mercury in the fish (Svobodová et al., 1996).

All indicator fish species proved the highest levels of total mercury content in Obříství and Lysá nad Labem localities. This section of the Elbe River is situated roughly between 120th and 160th river kilometre. A high mercury content was also found in the muscle of bream from Hřensko locality (5th r. km). Randák (2004) also reported that Obříství locality (downstream from the Spolana Neratovice Chemical Plant) was the most contaminated locality on the Elbe River, namely by metals and organic pollutants (PCB, HCB, DDT and its metabolites, alkylphenols). The absence of a sufficient number of chub males (only two males among the eight caught individuals of chub) is further evidence of damage to the fish population in this area (especially the male population of chub). Fish caught in this locality displayed serious pathological changes, namely in gonads. One of the highest concentrations of vitellogenin was found in the blood plasma of two males. Vitellogenin, an egg yolk precursor protein, is used as a suitable and valuable biomarker of reproductive disruption in fish (Kime et al., 1999). Vitellogenin is a biochemical marker for environmental endocrine disruptors (EEDs) (Kime et al., 1999). Besides organic pollutants (PCB, HCB, DDT and its metabolites alkylphenols) endocrine disruption may also be caused by mercury compounds (Keith, 1997).

In the years 1991–1996 repeated observations of the total mercury concentrations in the muscle of different species of fish were done in 13 localities of the Elbe River (Dušek et al., 2005). Čelákovice, Neratovice (from 144th to 122nd r. km), Děčín and Hřensko (from 15th to 5th r. km) were identified as the most contaminated localities. A comparison with the results of analyses from the period 1999–2003 shows that in the area from 160th to 120th river kilometre mercury contamination remained at the same level. On the other hand, in the area from 15th to 5th river kilometre a high decrease in mercury contamination of fish was found in 1999–2003. This promising result corresponds with measures taken by the Spolchemie Company in Ústí nad Labem. Essential measures were taken in the late 90ties of the last century, when mercury

was eliminated from the area of this chemical plant. This procedure resulted in decreased transfer of mercury to the Bílina River and subsequently to the Elbe (40th r. km). As reported by Kalinova (2004), the mercury load in waters of the Bílina River decreased substantially from 1995 to 2003 in Ústí nad Labem (i.e. before the confluence with the Elbe River). In 1995 it was repeatedly found out that the waters of the Bílina River carried values of mercury in intervals 30 μg/l, and a value of 83 μg/l was also found. Despite this marked decrease in mercury content in 2003, the immission standard limit 0.1 μg/l was not met (according to Table 1, Annex 3, Government Regulation 61/2003). Analogously to the territory of the Czech Republic, a continuous decrease in mercury contamination was observed in the German stretch of the Elbe River. For example Furrer et al. (1997) published findings of the tendency of a marked decrease in mercury content in the bottom sediment of the Elbe River from 1992 to 1994. Such a decrease in mercury content in the bottom sediment from the Elbe River estuary to the Northern Sea was reported by Gaumert (1992) already in the period 1986–1990.

A comparison of total mercury content in the muscle of bream and perch from the years 2002 and 2003 was used to evaluate possible effects of disastrous floods which affected the whole drainage area of the Elbe River.

Concerning the bream from particular localities that were examined at regular intervals, the levels of mercury remained nearly the same. Similar results were observed in perch with the exception of Valy locality (significant increase) and Lysá nad Labem locality (significant decrease). In the meantime, it has been impossible to assess the influence of disastrous floods on the basis of current findings. However, it is possible that variations in the contamination of sediments will affect the contamination of fish over the next few years.

Kannan et al. (1998) introduced the calculation of hazard index concerning fish consumption. This method was used to classify possible health hazard resulting from mercury content in fish. Hazard index below 1 means no risk for consumers. Average consumption of freshwater fish in the Czech Republic is 1 kg per capita/year. But fishermen and their families could be an exception because their fish consumption is assumed to amount up to 10 kg per capita/year (Berka, 1998). The highest content of total mercury in fish muscle 2.56 mg/kg fresh muscle (chub, Obříství) was taken for the calculation of hazard index.

Using the above-mentioned values hazard indexes 0.33 and 3.3 were calculated for ordinary consumers and consumers from families of fishermen, respectively. These values pose no hygienic hazards for the ordinary consumers; but they do pose high hygienic hazard for consumers from families of fishermen.

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