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Toxicology

**STUDIES ON MERCURY CONTENT IN MUSCLES
OF FISHES FROM SOME NATURAL POLISH WATER BODIES**

**BADANIA NAD ZAWARTOŚCIĄ RTĘCI W MIĘŚNIACH RYB POCHODZĄCYCH
Z NIEKTÓRYCH NATURALNYCH ZBIORNIKÓW WODNYCH POLSKI**

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Total mercury contents were determined in muscles of 16 fish species caught in the river Vistula, its tributaries, and the Łęczyca-Włodawa lakes. All the Vistula fishes examined showed much higher mercury contents compared to those found in fishes from unpolluted waters; mercury contents in many predatory fishes exceed 0.5 mg/kg^{-1} .

INTRODUCTION

A wide application of mercury and its compounds and a constantly increasing use there of combined with a lack or a poor efficiency of sewage and smoke treatment installations cause a steady increase in pollution of the natural environment and pose a danger of toxic effects. Particularly vulnerable to this element or its compounds are water habitats. Most of the mercury content enters the waters via industrial wastes and precipitation (Anderson et al., 1973).

Mercury entering a water habitat is accumulated in organisms living in it. Both methyl-mercury and inorganic mercury compounds show an affinity to sulpho groups of proteins (Gavis and Ferguson, 1972) and for this reason are rather permanently bound in an organism. Owing to a low excretion rate they tend to accumulate in the organism affected.

The mercury accumulation in fish tissues depends on a compound in question and its content in the environment, water temperature, and fish species (Barber et al., 1972; Giles and Scott, 1971; Hannerz, 1968; Hasselrot, 1968; Kramer and Neidhart, 1975; Tsai et al., 1975).

Various sympatric fish species can show markedly differing mercury contents, which is related to differences in metabolic processes of each species. Predatory fishes, pike in particular, tend to accumulate higher quantities of mercury; the species is therefore regarded as an indicator for determining the degree of mercury contamination in the aquatic habitat (Fageström et al., 1974; Fageström et al., 1975; Johnels et al., 1967; Johnels et al., 1968).

The present studies were aimed at determining the total mercury level in muscles of various fish species in the river Vistula.

Assuming the river to be polluted with industrial wastes, possibly the same species from unpolluted rivers and lakes were examined, too. The present work is a continuation of the author's studies on heavy metal contamination in fishes in Poland and Czechoslovakia (Hejtmánek et al., 1975; Studnicka, 1974; Studnicka et al., 1974; Svobodová et al., 1975 a; Svobodová et al., 1975 b).

MATERIAL AND METHODS

Total mercury was determined in muscles of 582 fish individuals belonging to 16 species.

Specimens from unpolluted waters were obtained from upper reaches of the following Vistula tributaries: Skawa, Dłubnia, and San, as well as from the river Tanew and the following Łęczyca-Włodawa lakes: Dratów, Łukcze, Rotcze, Sumin, Miejskie, and Kunów. The water bodies listed above yielded 94 individuals belonging to 10 species.

In the Vistula, known to carry a large load of industrial pollution, the fishes were caught at four sites: near Cracow, Puławy, Świecie, and Świbno (at the river mouth). Decisive for the selection of capture sites was the location of fishermen's cooperatives regularly fishing the species studied on the commercial basis.

Owing to a considerable pollution of the Vistula near Cracow with various toxic substances, only a small number of fish species is found to live there. Those fishes are not fit for consumption, no regular fishing is therefore carried out there; the material to be examined, consisting of 40 individuals belonging to 3 species had to be caught with a fishing rod.

The samples obtained near Puławy and Świecie consisted of 166 individuals belonging to 10 species and 125 individuals representing 8 species, respectively. Near Świbno, the mercury content was determined in muscles of 147 individuals belonging to 8 species.

The distribution of species among the capture sites is presented in Table 1.

The individuals caught were kept in polythene bags at -20°C . Each 5 g sample was taken from the central part of the supra-axial muscle. The sample was subject to wet

Table 1

Species studied at various capture sites

No.	Species	Capture sites				
		unpolluted waters*	Cracow	Puławny	Świecie	Świbno
1.	<i>Esox lucius</i> – (pike)	+		+	+	+
2.	<i>Aspius aspius</i>			+	+	+
3.	<i>Perca fluviatilis</i> – (perch)			+	+	+
4.	<i>Lucioperca lucioperca</i> – (pikeperch)			+		+
5.	<i>Leuciscus cephalus</i> – (chub)	+	+	+	+	
6.	<i>Anguilla anguilla</i> – (eel)	+				+
7.	<i>Barbus barbus</i>				+	
8.	<i>Ictalurus nebulosus</i> –	+				
9.	<i>Cyprinus carpio</i> – (carp)	+	+			
10.	<i>Rutilus rutilus</i> – (roach)	+		+	+	+
11.	<i>Abramis brama</i> – (bream)	+		+	+	+
12.	<i>Leuciscus leuciscus</i> –	+				
13.	<i>Leuciscus idus</i> – (ide)			+	+	+
14.	<i>Chondrostoma nasus</i> – (undermouth)	+		+		
15.	<i>Alburnus alburnus</i> – (bleak)		+	+		
16.	<i>Salmo gairdneri</i> – (rainbow trout)	+				
Total		10	3	10	8	8

* upper reaches of Skawa, Dłubnia, San; river Tanew; Łęczycza-Włodawa lakes

Table 2

Total mercury content in muscles of fishes from unpolluted lakes and rivers

Species	Capture site	Fish weight (g)	No of samples	Hg content (mg kg ⁻¹)	
				Range	Mean \pm s
<i>Esox lucius</i> (pike)	Lake Sumin	350–950	16	0.095–0.120	0.106 \pm 0.01
„	Lake Dratów	350–960	5	0.085–0.125	0.103 \pm 0.01
„	Lake Firlej	800–1650	5	0.070–0.150	0.100 \pm 0.02
„	Lake Kunów	840–1700	4	0.060–0.160	0.090 \pm 0.04
<i>Ictalurus nebulosus</i>	Lake Miejskie	60–96	10	0.037–0.111	0.064 \pm 0.02
<i>Anguilla anguilla</i> (eel)	Lake Rotcze	700–1500	4	0.040–0.085	0.058 \pm 0.02
<i>Rutilus rutilus</i> (roach)	Lake Łukcze	50–70	5	0.033–0.057	0.046 \pm 0.02
<i>Abramis brama</i> (bream)	Lake Łukcze	300	1	0.033	0.033
<i>Cyprinus carpio</i> (carp)	Lake Łukcze	50–150	15	0.006–0.042	0.025 \pm 0.02
<i>Leuciscus cephalus</i> (chub)	river Tanew	80–96	4	0.030–0.060	0.050 \pm 0.01
<i>Leuciscus cephalus</i> (chub)	river Skawa	130–170	15	0.020–0.047	0.029 \pm 0.04
<i>Leuciscus cephalus</i> (chub)	river San	80–100	3	0.006–0.016	0.011 \pm 0.01
<i>Chondrostoma nasus</i> (undermouth)	river Tanew	390	1	0.086	0.086
<i>Leuciscus leuciscus</i>	river Tanew	45–100	5	0.030–0.095	0.065 \pm 0.02
<i>Salmo gairdneri</i> (rainbow trout)	river Dłubnia	150	1	0.007	0.007

s = \pm standard deviation

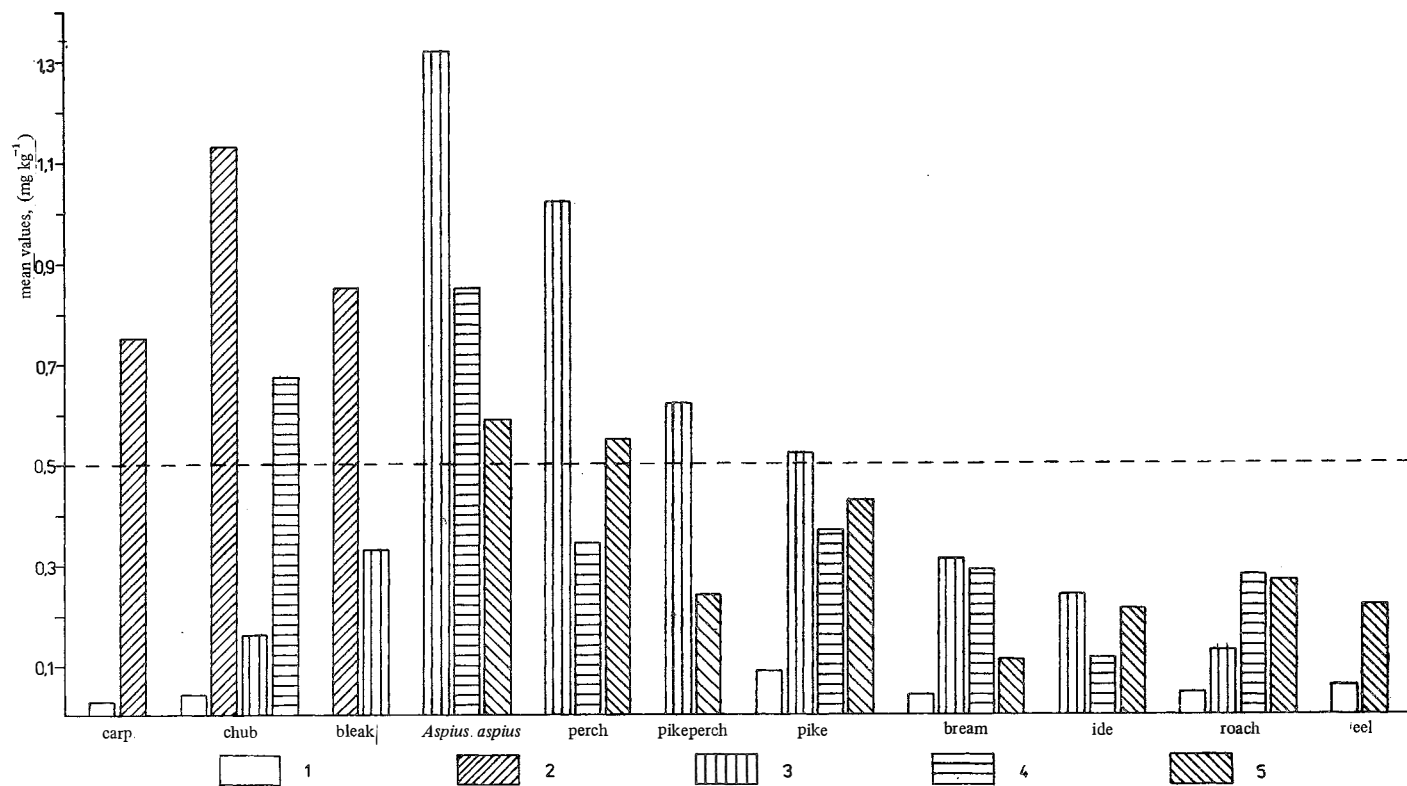


Fig. 1. Total mercury content in muscles of fishes from various capture sites 1. unpolluted waters; 2. Cracow; 3. Puławy; 4. Świecie; 5. Świbno

mineralization with nitric and sulphuric acids in a closed system (Szprengier, 1972; Żmudzki and Szprengier, 1973). Total mercury was determined by atomic absorption spectrophotometry in a Coleman MAS-50 (Perkin-Elmer) analyzer at the Department of Pharmacology and Toxicology, Institute of Veterinary Medicine (Puławy) and in an EEL 240 (Evans) atomic absorption spectrophotometer at the Central Laboratory, Academy of Agriculture (Lublin). Of the latter batch, some samples of a particularly high mercury content were checked at the Chair of Analytical Methods, Chemical-Technological College (Praha, Czechoslovakia).

The results obtained were subject to a statistical treatment.

RESULTS

Tables 2–6 summarize the total mercury contents in the fishes studied at various capture sites.

When analyzing the results obtained, the following data should be given a particular attention:

1. The total mercury content in those fishes caught from unpolluted lakes and rivers (Table 2) ranged within 0.006–0.16 mg kg⁻¹.
2. Of all the species obtained from clean water bodies, the highest mercury content, 0.06–0.16 mg kg⁻¹ (a mean of 0.1 mg kg⁻¹) was found in pike.
3. About 95% of all the individuals from those water bodies showed mercury contents below 0.1 mg kg⁻¹.
4. Individuals belonging to the same species but caught at different, sometimes very far apart, unpolluted lakes or rivers showed similar muscle mercury contents, which is clearly seen when comparing the mercury contents in chub or pike (Table 2).
5. All the Vistula fishes yielded much higher mercury contents compared to their counterparts from unpolluted waters (Table 7; Fig. 1).

Table 3

Total mercury content in muscles of fishes caught from the Vistula near Cracow

Species	Fish weight (g)	No. of samples	Hg content (mg kg ⁻¹)	
			Range	Mean s
<i>Leuciscus cephalus</i> (chub)	90–120	15	0.93–1.30	1.150 ± 0.06
<i>Alburnus alburnus</i> (bleak)	18–25	20	0.65–1.00	0.850 ± 0.25
<i>Cyprinus carpio</i> (carp)	80–110	5	0.69–0.95	0.797 ± 0.04

s = ± standard deviation

Table 4

Total mercury content in muscles of fishes caught from the Vistula near Puławy

Species	Fish weight (g)	No. of samples	Hg content (mg kg ⁻¹)	
			Range	Mean s
<i>Aspius aspius</i>	1000–1350	2	1.350–1.362	1.356
<i>Perca fluviatilis</i> (perch)	80–300	12	0.586–1.581	1.083 ± 0.49
<i>Lucioperca lucioperca</i> (pikeperch)	600–800	16	0.606–0.648	0.626 ± 0.04
<i>Esox lucius</i> (pike)	300–850	16	0.509–0.595	0.565 ± 0.03
<i>Alburnus alburnus</i> (bleak)	20–30	12	0.300–0.390	0.325 ± 0.03
<i>Abramis brama</i> (bream)	140–340	26	0.217–0.437	0.312 ± 0.09
<i>Leciscus idus</i> (ide)	280–646	29	0.100–0.495	0.240 ± 0.15
<i>Chondrostoma nasus</i> (undermouth)	330–800	11	0.219–0.329	0.224 ± 0.03
<i>Leuciscus cephalus</i> (chub)	40–125	18	0.117–0.166	0.152 ± 0.01
<i>Rutilus rutilus</i> (roach)	30–110	24	0.072–0.239	0.129 ± 0.04

s = ± standard deviation

Table 5

Total mercury content in muscles of fishes caught from the Vistula near Świecie

Species	Fish weight (g)	No. of samples	Hg content (mg kg ⁻¹)	
			Range	Mean s
<i>Aspius aspius</i> –	550–2360	14	0.350–1.119	0.862 ± 0.32
<i>Leuciscus cephalus</i> (chub)	700–1600	12	0.480–0.880	0.680 ± 0.20
<i>Barbus barbus</i> –	920	1	0.500	0.500
<i>Esox lucius</i> – (pike)	230–420	19	0.290–0.470	0.364 ± 0.07
<i>Perca fluviatilis</i> (perch)	50–170	25	0.205–0.379	0.362 ± 0.03
<i>Abramis brama</i> (bream)	180–620	19	0.120–0.430	0.294 ± 0.80
<i>Rutilus rutilus</i> (roach)	130–430	17	0.220–0.540	0.272 ± 0.35
<i>Leuciscus idus</i> (ide)	110–250	18	0.103–0.280	0.115 ± 0.11

s = ± standard deviation

Table 6

Total mercury content in muscles of fishes caught from the Vistula near Świbno

Species	Fish weight (g)	No. of samples	Hg content (mg kg ⁻¹)	
			Range	Mean _s
<i>Aspius aspius</i> –	800–2100	17	0.371–0.880	0.594 ± 0.18
<i>Perca fluviatilis</i> (perch)	100–420	22	0.249–0.894	0.551 ± 0.26
<i>Esox lucius</i> (pike)	350	1	0.432	0.432
<i>Rutilus rutilus</i> (roach)	180–830	23	0.100–0.400	0.265 ± 0.09
<i>Lucioperca lucioperca</i> (pikeperch)	750–2500	20	0.174–0.455	0.237 ± 0.08
<i>Anguilla anguilla</i> (eel)	200–1650	38	0.021–0.460	0.226 ± 0.08
<i>Leuciscus idus</i> (ide)	250–490	17	0.143–0.280	0.212 ± 0.04
<i>Abramis brama</i> (bream)	50–400	19	0.043–0.125	0.111 ± 0.02

s = ± standard deviation

6. All the Vistula fishes caught in the vicinity of Cracow showed their muscle mercury contents to exceed 0.5 mg kg⁻¹ (Table 3).
7. Muscles of predatory species (*Aspius aspius*, perch, pikeperch, pike) contained more mercury than those of omnivorous (chub, eel) or herbivorous species caught at the same sites (Table 7; Fig. 1).
8. Among the species caught at various Vistula sites, the *Aspius aspius* individuals showed the highest mean mercury content (Tables 4, 5, and 6).

DISCUSSION

The total mercury contents found in muscles of the examined fishes from unpolluted waters are within the range (0.006–0.16 mg kg⁻¹) accepted as a "natural level". Values similar to those reported here were found by other authors working on fishes from various unpolluted water bodies (Aronson et al., 1976; Studnicka et al., 1974; Svobodová et al., 1975; Weigand-Eschrachi et al., 1971; Zitko et al., 1971). As shown by the existing literature, muscle mercury levels in fishes of various species inhabiting unpolluted waters do not differ in any significant way. On the other hand, in polluted waters much higher mercury contents are found in predatory species than in omni- and herbivores

(Hajtmánek et al., 1975; Svobodová et al., 1975; Uthe and Bligh, 1971; Wobeser et al., 1970). The data obtained in the present study corroborate previous results.

The results obtained in the present study show all the Vistula species tested, regardless of the capture site, to be of a higher mercury content (up to 1.581 mg kg^{-1}) than the fishes caught in the unpolluted water bodies. The degree of pollution tends to vary along the Vistula course, which can be seen by comparing mercury contents in muscles of conspecific individuals of a similar weight caught at various sites (Table 7; Fig. 1).

All the fishes caught in the vicinity of Cracow (Table 3; Fig. 1) showed their mercury contents in muscles to exceed 0.5 mg kg^{-1} , i.e., a content proposed by FAO/WHO as the highest content permitted in marketed fish (Technical Reports, 1972). Among the species caught off Cracow, chub was found to have the highest mercury content (a mean of 1.15 mg kg^{-1}) whereas chub caught in the unpolluted rivers (upper reaches of San, Skawa, and Tanew) showed much lower mercury contents (a mean of 0.03 mg kg^{-1}). A considerable contamination of all the fishes caught off Cracow proves a high degree of pollution to occur in that part of the Vistula brought about — as should be assumed — by a substantial amount of wastes released by numerous industrial plants. This pollution includes, apart from mercury, other substances toxic for fishes, which is evidenced by a scanty ichthyofauna in that part of the river.

Table 7

Mean total mercury content (mg kg^{-1}) in muscles of fishes from various capture sites

No.	Species	Capture site				
		Unpolluted waters*	Cracow	Puławy	Świecie	Świbno
1	<i>Esox lucius</i>	0.100		0.565	0.364	0.432
2	<i>Aspius aspius</i>			1.356	0.862	0.594
3	<i>Perca fluviatilis</i>			1.083	0.362	0.551
4	<i>Lucioperca lucioperca</i>			0.626		0.237
5	<i>Leuciscus cephalus</i>	0.030	1.150	0.152	0.680	
6	<i>Anguilla anguilla</i>	0.058				0.226
7	<i>Barbus barbus</i>				0.500	
8	<i>Ictalurus nebulosus</i>	0.064				
9	<i>Cyprinus carpio</i>	0.025	0.797			
10	<i>Rutilus rutilus</i>	0.046		0.129	0.272	0.265
11	<i>Abramis brama</i>	0.033		0.312	0.294	0.111
12	<i>Leuciscus leuciscus</i>	0.065				
13	<i>Leuciscus idus</i>			0.240	0.115	0.212
14	<i>Chondrostoma nasus</i>	0.086		0.224		
15	<i>Alburnus alburnus</i>		0.850	0.325		
16	<i>Salmo gairdneri</i>	0.007				

* upper reaches of Skawa, Dłubnia, San; river Tanew; Łęczyca-Włodawa Lakes

In the vicinity of Puławy, mercury contents exceeding 0.5 mg kg^{-1} were found only in the predatory species (*A. aspius*, perch pikeperch, pike) (Table 4; Fig. 1). This part of the Vistula yields fish for consumption. According to a standard proposed for Poland (0.5 mg kg^{-1} ; Szprengier, 1976) it follows that the predatory species caught in that part of the river should not be allowed for consumption. The decision banning the marketing of those fishes should be, however, preceded by periodical checks of the fish mercury content.

When analyzing the mercury contamination in the fishes caught in the vicinity of Świecie, a lower mercury content is observed compared to the fishes caught off Puławy (Fig. 1). It was only in two species (*A. aspius* and chub) that a mean mercury content exceeded 0.5 mg kg^{-1} . With respect to the predatory species, no pike or perch individual showed a mercury content exceeding 0.5 mg kg^{-1} .

The degree of mercury contamination in herbivores and benthosfeeders caught off Świecie (Table 5; Fig. 1) was also lower than off Puławy in spite of the fact that those fishes were usually heavier (bream and roach in particular) and as such they should have been expected to have accumulated more mercury in their muscles. It seems probable that this was the reason of a high mercury content in chub caught in this part of the river. Those fishes weighed up to 1600 g, their mean mercury content being 0.68 mg kg^{-1} , while much smaller (40–125 g) individuals of the species caught off Puławy showed a mean mercury content of 0.15 mg kg^{-1} . Older chub, however, switch to a predatory mode of feeding. This factor seems thus to play a key role in increasing the mercury content in those individuals caught in the vicinity of Świecie.

The results obtained can serve as a basis for a general conclusion that the Vistula in the vicinity of Świecie is mercury-polluted to a lesser extent than off Puławy.

The results obtained in the vicinity of Świbno (Table 6; Fig. 1) allow no specific conclusion on the pollution extent in that part of the river to be drawn.

A lower mercury content there as compared to the vicinity of Świecie was found in *A. aspius* and bream. The latter was, however, represented by individuals of a lower weight than off Świecie. Muscles of another two species, perch and ide, showed a higher mercury content off Świbno than in the vicinity of Świecie, which could have resulted from a larger size, and consequently an older age of the Świbno individuals.

Although *A. aspius* and perch in that part of the Vistula showed a mean mercury content exceeding 0.5 mg kg^{-1} , which – according to a proposed Polish standard – is more than the permitted level, it should be stressed that 50% of the individuals of the two species showed their mercury contents to be below that value, as was the case in all pikeperch and pike individuals caught in that part of the river.

Among all the species examined, the Świbno bream muscles showed the lowest mercury content ranging within $0.043\text{--}0.0125 \text{ mg kg}^{-1}$, i.e., close to the "natural level" found in bream from the unpolluted waters (Table 7). The mercury content was close to the "natural level" also in 25% of eel individuals tested.

Similar mercury contents were found by Nabrzyski (1975) in fishes from the lower reach of the Vistula and Nogat.

Generally speaking, the degree of mercury contamination in the Vistula fishes is found to be considerable, particularly in the predatory species. Herbivores and benthos-feeders showed their muscle mercury contents to be below 0.5 mg kg^{-1} (except for those individuals caught in the vicinity of Cracow). The data suggest a straightforward relationship to exist between the degree of mercury accumulation and food chain length.

The Vistula fish mercury contamination is similar to that found in fishes from various European countries. Muscles of fishes caught at various sites along the entire course of the Vltava (Czechoslovakia), showed the total mercury contents below 0.5 mg kg^{-1} (Studnicka et al., 1974), while 26% of those analyzed from the river Ohře and its tributary Reslava crossing an industrialized region of the country showed their mercury contents to exceed this level (Svobodová et al., 1975 a). Fishes from the West Germany section of the Danube revealed a mean mercury content ranging from 0.20 to 0.87 mg kg^{-1} , depending on the species (Knöppler and Dorn, 1976). The fish muscle mercury contents in various water bodies of the Federal Republic of Germany showed a mean value of 1.9 mg kg^{-1} (Dietz and Koppe, 1972). In other studies, the fishes from the Danube in the southern part of the FRG showed a high mercury content (0.4 – 1.9 mg kg^{-1} ; Wiesner, 1972). The fishes from running waters of that country showed their mercury contents lower than those found in dam reservoir fishes by the factor of 8 (Wiesner, 1972). The Danube and its tributaries in Austria is relatively weakly polluted: in 60% of the fishes examined, the muscle mercury content was below 0.5 mg kg^{-1} , the highest value amounting to 1.9 mg kg^{-1} (Krocza et al., 1975). A high mercury content was recorded in the fishes caught in the Danube off Vienna (Otte et al., 1973). Fishes from lakes and rivers of central Italy are substantially mercury-contaminated, particularly those from the river Pescara receiving wastes of large industrial plants. The fishes from that river showed the mercury content ranging within 0.48 – 19.30 mg kg^{-1} . The mercury content in fish muscles in other Italian rivers did not exceed 0.63 mg kg^{-1} (Caracciolo et al., 1972). Eel caught in various Dutch water bodies showed a much higher mercury contamination (Nuijt and Velden, 1973) than eel from Świbno. A high mercury content was found also in fishes from Scandinavian waters, considerably polluted with industrial wastes (Berlund and Wretling, 1967; Berlund et al., 1970; Westöö and Rydälw, 1971).

CONCLUSIONS

1. The river Vistula fishes, particularly those caught in the vicinity of Cracow, are highly contaminated with mercury compounds. The total mercury content in all the Cracow fishes examined and in many species (particularly predators) from other parts of the river was found to exceed 0.5 mg kg^{-1} , i.e., the value determined by FAO/WHO and proposed for Poland as the highest permitted level in fish for consumption. It follows that the marketed Vistula fishes (particularly the predatory species) should be periodically checked for the degree of their mercury contamination.

2. Mercury accumulation was found to be higher in the predatory species and in larger individuals than in herbivores and smaller ones, which seems to result from a gradually increasing mercury compound concentration in tissues occurring both in consecutive links of food chains (in the predators) and during extended time periods (in older individuals).

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Maria Studnicka

BADANIA NAD ZAWARTOŚCIĄ RTĘCI W MIĘŚNIACH RYB POCHODZĄCYCH Z NIEKTÓRYCH NATURALNYCH ZBIORNIKÓW WODNYCH POLSKI

Streszczenie

Poziom rtęci całkowitej oznaczano w mięśniach 582 ryb należących do 16 gatunków.

Badano ryby z wód nieskażonych – z górnego biegu trzech dopływów Wisły: Skawy, Dłubni, Sanu; z rzeki Tanwi oraz jezior łęczyńsko-włodawskich. W Wiśle, której wody są zanieczyszczone ściekami przemysłowymi odławiano do badań ryby w czterech punktach: w okolicy Krakowa, Puław, Świecia i Świbna.

Oznaczenia rtęci wykonano metodą spektrofotometrii atomowo-absorpcyjnej.

Stężenia rtęci całkowitej w mięśniach ryb z wód nieskażonych wahało się w granicach 0,006–0,16 mg/kg, a u 95% tych ryb wynosiło poniżej 0,1 mg/kg.

Wszystkie badane ryby z Wisły, niezależnie od miejsca odłowu, zawierały w tkance mięśniowej znacznie wyższe stężenia rtęci (sięgające do 1,58 mg/kg) aniżeli ryby odłowione w wodach nieskażonych. Stopień skażenia ryb z Wisły związkami rtęci jest znaczny, zwłaszcza ryb drapieżnych. U ryb roślinożernych oraz odżywiających się drobną fauną denną poziom rtęci w mięśniach nie przekraczał wartości 0,5 mg/kg (z wyjątkiem okolic Krakowa). Dane te sugerują, że istnieje prosta zależność stopnia gromadzenia rtęci od długości łańcucha pokarmowego.

M. Студницка

ИССЛЕДОВАНИЕ СОДЕРЖАНИЯ РТУТИ В МЫШЦАХ РЫБ НЕКОТОРЫХ ЕСТЕСТВЕННЫХ РЕЗЕРВУАРОВ ПОЛЬШИ

Р е з ю м е

Уровень общей ртути определяли в мышцах 582 рыб 16 видов. Исследовали рыб из незагрязненных вод – из верхнего течения 3 притоков реки Висла: Скава, Длубня, Сан, из реки Танви а также из озер ленчино-влодавских. В Висле, воды которой загрязнены промышленными сточными водами, рыб для исследования вылавливали в 4 местах – в районе городов: Краков, Пулавы, Свеция и Свибно. Ртуть определяли методом атомно-абсорбционной спектрофотометрии. Концентрация общей ртути в мышцах рыб из незагрязненных вод колебалась в пределах 0,006 – 0,16 мг/кг и у 95% этих рыб была ниже 0,1 мг/кг. Все исследованные рыбы из реки Висла независимо от места вылова содержали в мышечной ткани значительно высшее количество ртути (доходящие до 1,58 мг/кг) чем рыбы отлавливаемых в незагрязненных водах.

Степень загрязнения рыб из реки Висла соединениями ртути является высокой, особенно хищных рыб. У растительноядных рыб а также рыб питающихся мелкой донной фауной, уровень ртути в мышцах не превышал 0,5 мг/кг (за исключением окрестностей Кракова). Эти данные дают основание предполагать, что существует прямая зависимость величины накопления ртути от длины пищевой цепи.

Received: 6 VI 1980

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