Polish Journal of Environmental Studies Vol. 9, No. 4 (2000), 335-339

Total Mercury Contamination of Some Fish Species in the Firth of Vistula and the Lower Vistula River, Poland*

J. Falandysz*, A. Chwir, B. Wyrzykowska

Department of Environmental Chemistry & Ecotoxicology, University of Gdansk, ul. Sobieskiego 18, PL 80-952 Gdańsk, Poland

Received: December 6, 1999
Accepted: January 18, 2000

Abstract

The muscle tissue samples of smelt *(Osmerus epelanus),* herring *(Clupea harengus),* sabrefish *(Pelecus cultratus),* roach *(Rutilus rutilus),* bream *{Abramis brama),* ruff *(Acerina cernua),* perch *(Perca fluviatilis),* pikeperch *(Stizostedion lucioperca),* flounder *(Platichthys flesus),* brown trout *(Salmo Irutta)* and burbot *(Lota lota)* collected in the Firth of Vistula, the Lower Vistula River at the Btotnik site and the Gulf of Gdansk in May and June 1997 have been analyzed for total mercury content. The method of mercury measurement was flameless cold-vapour atomic absorption spectroscopy (CV-AAS) after wet digestion of the samples with concentrated nitric acid in a whole glass system. The study indicated around twice higher concentrations of Hg in fish collected from the Lower Vistula River than from the Firth of Vistula. Total mercury concentrations for a relatively large number of the specimens (between 12 and 41) of bream, perch, ruff, herring, flounder and pikeperch caught in the Firth of Vistula correlated ($0.05 < p < 0.01$) with total body length and body weight (age) of fish. Any of the fish species examined contained mercury at concentrations exceeding 300 ng/g wet weight. Nevertheless, smelt, herring, sabrefish and ruff were the only mature specimens, while other fish examined were rather of small body size. An ongoing study on mercury in the ecosystem of the Lower Vistula River will further focus on a larger number of fish species, specimens and including individuals large in body size.

Keywords: mercury, fish, Firth of Vistula, Vistula River, Gulf of Gdansk

Introduction

Both the Lower Vistula River and the Firth of Vistula (Zalew Wislany) are located in a flat and mainly farmland area of Poland (Fig. 1). The Vistula (Wisla) River is the longest river in Poland (total length 1068 km), and due to the size of the watershed area (193,910 km^2) and volume of water runoff (954 m^3/s), it is an important source of nutrients, and somewhat less so of persistent and toxic chemicals transported to the Gulf of Gdansk and the Gdansk Basin in the Baltic Sea. The nutrients (e.g. phosphor and nitrogen) transported *via* the Vistula River to the Baltic Sea are mainly consumed in a coastal zone of the Gulf of Gdansk nearby to the outlet of that river [1]. Mercury and probably also other persistent pollutants that are readily adsorbed onto a fine suspended matter, apart from the sedimentation in a coastal mixing zone in part are also successively transported east and northeast of the river outlet, towards to the Depth of Gdansk. The Depth of Gdansk is a site of natural sedimentation of organic matter in the Gdansk Basin. The total area of the Firth of Vistula is 838 km^2 and 328 km^2 belongs to Poland. Depth is 2.6 m, on the average (up to 5.1 m maximum). The hydrographic situation in the Firth of Vistula till 1915 was mainly under direct impact of the Nogat River, which was a main arm of the

Correspondence to J. Falandysz; e-mail: jfalandy@chemik.chem.univ.gda.pl

Vistula River (Fig. 1). In 1916 a canal lock was established to separate both rivers at the site of Matowski Cypel, and the inflow of water of the Vistula River become regulated - in practice there is no inflow. From 1916 the basin of the Firth of Vistula is in part a mixing area of the salt water - coming throughout the Pilawska Strait, and fresh water due to inflow through small rivers, streams and drainage canals.

Mercury is a highly toxic element and in recent decades a main source of environmental pollution mainly because of anthropogenic emissions due to the use of hard coal, brown coal and other fossil fuels, and also due to uncontrolled waste combustion [2-5]. In some areas of the world continuous use of mercury to amalgamate particulate gold as well as in chlor-alkali plants still cause extensive environmental pollution by that element [6-7]. In Poland hard coal and brown coal are also considered to be an important source of emissions of mercury to the atmosphere [8]. Nevertheless, emission and deposition rates, budget or quantitative assessment of environmental contamination by mercury and including various sources and a whole area of the country are lacking in detail. In the past (1954 ~ 1980) in Poland five organomercury compounds were used for dressing of seed but due to relatively low application rates (~ lg of Hg per hectare in 1956-1970, and ~ 1.7g in 1969-1970) and degradability did not have much impact on the environment [9]. Industrial use of imported mercury quotas (183-209 tonnes yearly) in Poland was between ~ 10 and ~ 30 times higher in 1970-1975 than of agrotechnical use (6-30 tonnes yearly), while the chlorine-alkali industry seemed to be a major recipient [9, 10]. There is no data available in detail on amounts and use of mercury imported to Poland after 1975.

This study reports the results of total mercury analysis conducted on muscle tissue of several species of fish caught in the Firth of Vistula, the Lower Vistula River and the Gulf of Gdansk in 1997.

Materials and Methods

The specimens of smelt *Osmerus eperlanus*, herring *Clupea harengus*, sabrefish *Pelecus cultratus*, roach *Rutilus rutilus*, bream *Abramis brama*, ruff *Acerina cernua*, perch *Perca flavescens*, pikeperch *Stizostedion lucioperca*, flounder *Platychthis flesus*, brown trout *Salmo trutta* and burbot *Lota lota* were caught using a gill net or bottom sack in the Firth of Vistula and in the Gulf of Gdansk at the Piaski site in May 24, 1997, and in the Lower Vistula River at the Blotnik site in June 21, 1997, respectively (Fig. 1, Table 1).

Muscle tissue samples were taken from the dorsal part of the fish body. For the determination of mercury samples (~ 1 g) were wet-digested with concentrated nitric acid (65% Suprapur®, Merck) in a whole glass apparatus and final determination was made using flameless cold-vapour atomic absorption spectroscopy (CV-AAS) using stannous chloride (97%, p.a., Merck) and with the aid of a fully automated 3200 Mercury

Table 1. Biometric data and total mercury concentration (mean, SD and range) in muscle tissue of fish from the Firth of Vistula, the Lower Vistula River and the Gulf of Gdansk.

Sampling site and species	n	Body length (cm)	Body weight (g)	Mercury (ng/g wet wt)
The Firth of Vistula				
Smelt	41	18 ± 5 (13 – 25)	22 ± 11 (9 – 65)	66 ± 28 (21 – 170)
Herring	52	21 ± 2 (17 – 26)	59 ± 13 (35 – 90)	86 ± 28 (28 – 140)
Sabrefish	16	31 ± 5 (27 – 41)	200 ± 111 (50 – 520)	88 ± 44 (25 – 180)
Roach	26	18 ± 2 (15 – 22)	72 ± 19 (36 – 120)	58 ± 34 (24 – 170)
Bream	12	16 ± 4 (11 – 21)	67 ± 29 (16 – 99)	69 ± 31 (28 – 110)
Ruff	30	15 ± 1 (13 – 18)	41 ± 6 (32 – 50)	66 ± 40 (15 – 120)
Perch	30	15 ± 1 (14 – 17)	41 ± 6 (32 – 50)	90 ± 35 (38 – 170)
Pikeperch	23	24 ± 4 (24 – 27)	113 ± 46 (22 – 172)	110 ± 55 (28 – 230)
Flounder	26	21 ± 2 (15 – 27)	109 ± 32 (50 – 210)	49 ± 24 (18 – 120)
The Lower Vistula River				
Roach	4	14 ± 1 (11 – 16)	40 ± 16 (19 – 57)	170 ± 40 (120 – 230)
Bream	6	14 ± 3 (11 – 18)	45 ± 29 (16 – 88)	160 ± 16 (130 – 180)
Brown trout	2	14 (14 – 14)	24 (24 – 24)	110 (100 – 110)
Perch	6	15 ± 1 (14 – 16)	41 ± 11 (27 – 56)	140 ± 20 (120 – 170)
Burbot	3	24 ± 1 (23 – 25)	140 ± 26 (109 – 170)	160 ± 35 (110 – 190)
The Gulf of Gdańsk				
Flounder	12	24 ± 1 (21 – 25)	140 ± 25 (120 – 200)	45 ± 25 (24 – 100)

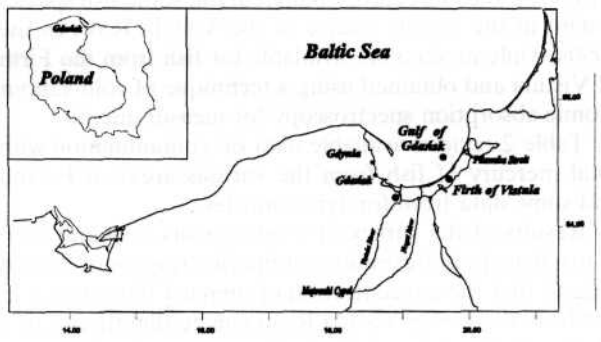

Fig. 1, Study area and fish collection sites (•).

monitor Thermo Separation Products, USA [11-13]. The analytical method used was validated on several occasions by analyzing certified biological reference materials, by participation in intercalibration trials and the within-run reproducibility control [11, 14]. Analytical blanks did not indicate the presence of mercury concentrations interfering (< 5%) with the smallest concentrations found in real samples.

Results and Discussion

The results of mercury analysis in fresh muscle tissue for fish examined are summarized in Table 1. In every fish sample mercury concentration did not exceeded a value of 300 ng/g wet weight. Smelt, herring, sabrefish and ruff collected from the Firth of Vistula were mature specimens, and in the case of the other fish species and sites only small-sized individuals were examined. In the case of the specimens collected from the Firth of Vistula a predatory pikeperch and perch showed highest contamination with mercury; nevertheless, only small individuals were available for analysis. There was a positive

Table 2. Comparision of total mercury concentrations (mean and range) in muscle tissue of fresh water fish species from some regions of the world.

Species	Area and year of sampling	n	Mercury (ng/g wet weight)		Reference
Roach	Vistula River, Poland,1996	1	100	–	18
	Puck Bay, Poland, 1995-97	3	81	69-94	22
	Region of Grodno, Belarus, 1996	3	30	30-45	24
	Bangladesh, 1997	19	67	27-110	25
	Firth of Vistula, Poland, 1997	26	58	24-170	This study
	Lower Vistula River, Poland, 1997	4	170	120-230	This study
Perch	Wisconsin, USA, 1985-87	–	130	110-140	23
	Vistula River, Poland, 1996	2	160	140-190	18
	Puck Bay, Poland, 1995-97	56	120	23-200	22
	Firth of Vistula, Poland, 1997	30	90	38-170	This study
	Lower Vistula River, Poland,1997	6	140	120-170	This study
Ruff	Region of Grodno, Belarus, 1996	15	30	15-45	24
	Firth of Vistula, Poland, 1997	30	66	15-120	This study
Pikeperch	Wisconsin, USA, 1985-87	68	150	120-170	23
	Firth of Vistula, Poland, 1997	23	110	28-230	This study
Bream	Vistula River, Poland , 1996	14	86	22-180	18
	Vistula River, Poland, 1993	–	110	28-230	20
	Puck Bay, Poland, 1995-97	5	40	32-52	22
	Firth of Vistula, Poland, 1997	12	69	28-100	This study
	Lower Vistula River, Poland, 1997	6	160	130-180	This study
Brown trout	Vistula River, Poland, 1973	–	35	13-59	21
	Lower Vistula River, Poland, 1997	2	110	100-110	This study
Flounder	Gulf of Gdańsk, Poland, 1993	41	93	16-220	26
	Gulf of Gdańsk, Poland, 1994	37	25	16-47	26
	Gulf of Gdańsk, Poland, 1995	65	75	11-400	26
	Puck Bay, Poland, 1995-97	66	39	15-210	22
	Baltic Sea, Poland, 1970-79	–	–	10-450	27
	Glomma estuary, Norway, 1993	80	150	–	28
	Firth of Vistula, Poland, 1997	26	49	18-120	This study
	Gulf of Gdańsk, Poland, 1997	12	45	24-100	This study
Herring	Puck Bay, Poland,1995-97	8	81	69-94	22
	Baltic Sea, 1970-1979	–	–	0-90	27
	Firth of Vistula, Poland, 1997	52	86	28-140	This study

relationship between total body length and weight and mercury concentration in muscle tissue for perch, bream and ruff ($p < 0.01$) as well as for herring, flounder and pikperch ($p < 0.05$) but no such correlation was found for sabrefish, smelt and roach caught in the Firth of Vistula. The number of fish species and specimens collected from the Vistula River was insufficient for a regression analysis. Small roach, bream and perch collected from the Lower Vistula River at the Blotnik site were twice more contaminated with mercury than the same species originating from the Firth of Vistula (Table 1).

The perch a in this study (both caught in the Firth of Vistula and the Lower Vistula River) were much higher contaminated with mercury than specimens collected in the western part of the Gulf of Gdansk in 1986-89, which contained in muscle tissue 75 ± 78 ng Hg/g wet weight (total range from 5 to 410 ng/g wet weight; n = 49; body weight between 35 and 685 g) [15]. Apart from perch, also herring and smelt from the Firth of Vistula in this study showed much higher mercury contamination than the specimens caught in the Gulf of Gdansk in 1988-90, i.e. 22 ± 15 ng Hg/g wet weight (total range from 5 to 64 ng/g wet weight; n = 109) and 12 ± 4 ng Hg/g (total range from 8 to 18 ng/g wet weight; n = 5), respectively [15].

There are no known natural deposits of mercury or mercury rich ores in the drainage area of the Vistula River and the Firth of Vistula. The western part of the Firth of Vistula is a water body remote from any known main sources of anthropogenic pollution with mercury. Soils of different types at the area of the Mierzeja Wislana sand-bar which separates the Firth of Vistula from the Gulf of Gdansk, are characterized by relatively small concentrations of mercury in the uppermost (0-10 cm layer) horizon [14]. Total Hg, methyl Hg and Hg (II) content of surface sediments collected from the upper edge of the Lower Vistula River at the site of the dam in the town Wfoclawek in 1994 was relatively low, i.e. 2.3, 0.042 and 0.32 ng/g dry weight, respectively, which is much lower than indicated for surface sediments from various sites in the Gulf of Gdansk (total Hg from 37 to 880 ng/g) [16].

In the case of the Vistula River a main source of anthropogenic mercury pollution still seems to be related in large part to untreated municipal sewage and industrial effluent, and storm water input from many towns and sites in the catchment area of the Vistula River in Poland. The contribution from the chlor-alkali industry has declined over the past decade due to a shut-down of some plants located along the bank of the Vistula River; however, there are no studies on this industry in Poland.

The Vistula River seems to be an important source of mercury pollution in the Gulf of Gdansk. Site-specific differences in spatial distribution of mercury concentrations were observed in flounder caught in the Gulf of Gdansk in 1992-1996. The flounder collected at the sites nearby and east to the outlet of the Vistula River were among the specimens most contaminated with mercury [17]. The significantly elevated concentrations of mercury in muscle tissue of flounder at the sites offshore and east of the Vistula River outlet in the Gulf of Gdansk (Fig. 1) are thought to be due to sewage contamination of the river. Nevertheless, the number of data on mercury in the Vistula River ecosystem is very limited [18-21]. There are only a few recent records on mercury in some fish species caught in the middle course of the Vistula River in the 1990s, while no data are available for fish from the Firth of Vistula and obtained using a technique of cold-vapour atomic absorption spectroscopy for measurement.

Table 2 reviews available data on contamination with total mercury of fish from the various areas of Poland and some data from foreign countries.

Results of the survey of total mercury concentration in fish from both freshwater andmarine regions of Poland suggest that the concentration of mercury determined in fish from the Lower Vistula River can be slightly elevated (Table 2). Fish large in body size are usually characterised by higher mercury concentrations in their flesh when compared to fish of the same species but small in body size [15, 17, 22]. Since all the fish specimens from the Lower Vistula River investigated in this survey (Table 1) can be considered as rather of small body size it can be possible to relate mercury concentration directly to the values presented for large sized roach, bream and perch caught in the middle course of Vistula River (~ 400 km up of the river outlet) as presented by other authors (Table 2).

Ongoing study on sources, concentrations, distribution and fate of mercury in the ecosystem of the Lower Vistula River will further focus on a larger number of fish species and specimens, including individuals relatively large in body size.

Acknowledgements

This study was partly supported by the Polish State Committee of Scientific Research (KBN), under grant DS no 8250-4-0092-9.

References

1. LYSIAK-PASTUSZAK E., DRGAS N. An immediate con sequences of the flood episode in July 1997 in the environ ment of the Gulf of Gdansk and the Pomeranian Bay (in Polish). Abstracts. Ill Konferencja ,,Chemia, geochemia i ochrona srodowiska morskiego" 12 grudnia, 1997 - Sopot. Sekcja Chemii Morza, Komitet Badan Morza, PAN. **1997.**
2. SLEMR F., LANGER E. Increase in global atmospheric concentrations of mercury inferred from measurements over the Atlantic Ocean. Nature **355,** 434, **1992.**
3. SLEMR F, JUNKERMANN W, SCHMIDT R.W.H., SLADKOWVIC R. Indication of change in global and re gional trends of atmospheric mercury concentrations. Geo physical Res. Lett. **22,** 2143, **1995.**
4. PIRRONE N., KELLER G.J, NRIAGU J.O. Regional dif ferences in worldwide emissions of mercury to the atmos phere. Atmosph. Environ. 30, 2981, **1996.**
5. HANISH C. 1998. Where is mercury deposition coming from? Environ. Sci. Technol. 32,176A, **1998.**
6. HACON S, ROCHERO E.R.R, CAMPOS R.R.R., LAC-ERDA L.D. Mercury exposure through fish consumption in the urban area of Alta Floresta in the Amazon Basin. J. Geochem. Expl. **58,** 209, **1997.**
7. CALASANS **C.F.,** MALM O. Elemental mercury contami nation survey in a chlor-alkali plant by use of transplanted

Spanish moss, *Tillandsia usneoides* (L.). Sci. Total Environ. 208, 165, 1997.
8. MNISZEK W. Emission of mercury to the atmosphere from industrial sources in Poland. Environ Monit Assessm.41, 291, 1996.
9. FALANDYSZ J. The use of pesticides and their levels in food in Eastern Europe: The example of Poland. Chapter 26 *In* Contaminants in the environment. A multidisciplinary as sessment of risks to man and other organisms. A. Renzoni, N. Mattei, L. Lari, and MC. Fossi. (Eds). CRC Press, Inc. ISBN 0-87371-853-4. pp 247-256, 1994.
10. SZPRENINGER T. Mercury in the environment - sources and contamination (in Polish). Proc 1st Natl Conf Effects of Trace Elements Pollutants on Agricultural Environment Quality. May 4-6, Putawy, Poland., pp.73-81, 1978.
11. FALANDYSZ J. Mercury content of squid *Loligo opalescens.* Food Chem. 38,171, 1990.
12. FALANDYSZ J. Mercury concentrations in benthic animals and plants inhabiting the Gulf of Gdansk, Baltic Sea. Sci. Total Environ.141, 45, 1994.
13. FALANDYSZ J., KOWALEWSKA M. Mercury concentra tion of stickleback *Gasterosteus aculeatus* from the Gulf of Gdansk. Bull. Environ. Contam. Toxicol. 5, 710, 1993.
14. FALANDYSZ J., CHWIR A. The concentrations and bio-concentration factors of mercury in mushrooms from the Mierzeja Wislana sand-bar, Northern Poland. Sci. Total En viron. 203, 221,1997.
15. FALANDYSZ J., PIOTROWSKA M., WLODARCZYK J, CHWIR A., MARCINOWICZ A. Total mercury content in fish from the Gulf of Gdansk. Stud. Mat. Oceanolog. Mar. Chem. 67, 59, 1994.
16. KANNAN K., FALANDYSZ J. Speciation and concentra tions of mercury in certain coastal marine sediments. Water, Air, and Soil Pollut. 103, 129, 1998.
17. FALANDYSZ J., PIOTROWSKA M. Mercury in the muscle tissue of flounder *Platichthys flesus* from two sites in the Gulf of Gdansk (in Polish). Roczn. Panstw. Zakt. Hig. 44, 119, 1995.
18. ZARSKI T.P., ZARSKA H. The level of mercury contamination of various species of fishes caught in the middle course of the Vistula River. Ann. Warsaw Agricult. Univ. - SGGW Vet. Med. 32, 65-69,1996.
19. ZARSKI T.P., ROKICKI E., DEBSKI B, SAMEK M. Mer cury distribution in the tissue of bream *(Abramis brama* L.) caught in the middle course of the Vistula river before the Bzura estuary. Ann. Warsaw Agricult. Univ. - SGGW Vet. Med. 18, 109, 1993.
20. ZARSKI T.P, DEBSKI B., BESEDA I., VALKA J. Mer cury pollution offish caught in 1990 and 1993, in the middle course of the Vistula River. Ekologia (R.S.). 1994.
21. STUDNICKA M. Mercury content of tissues of brown trout *(Salmo trutta morpha trutta)* caught near the Vistula River outlet (in Polish). Medycyna Wet. 30, 739, 1974.
22. FALANDYSZ J., BOSZKE L. Total mercury in muscle tis sue of edible species offish from Puck Buy (in Polish). Bro-mat. Chem.Toksykol. 32, 75, 1999.
23. WIENER J.G. Metal contamination of fish in low-pH lakes and potential implications for piscivorous. Wildlife.Trans.52nd N. A. Wildl. And Nat. Res. Conf. pp 645-657. 1987.
24. ZARSKI T.P., ZARSKA H. Contamination of various spe cies of slaughter animals and fish by mercury in the Grodno region (in Polish). Medycyna Wet. 55, 477, 1997.
25. HOLSBEEK L., DAS H.K, JOIRIS C.R. Mercury speci ation and accumulation in Bangladesh freshwater and an-dromogous fish. Sci. Total. Environ. 198, 201, 1997.
26. PIOTROWSKA M. Badania nad rozmieszczeniem przes-trzennym i tendencjami czasowymi zmian zawartosci rteci w rybach z Zatoki Gdanskiej. Praca doktorska. Uniwersytet Gdanski. 1997.
27. BRZEZINSKA A., TRZOSINSKA A. Trace metals in some organisms from the Southern Baltic. Oceanologia. 18, 79, 1984.
28. STAVELAND G., MARTHINSEN I., NORHEIM G., JULSHAMN K. Levels of environmental pollutants in floun der *(Platichthys flesus L.)* and cod *(Gadus morhua L.)* caught in waterway of Glomma, Norway. II. Mercury and arsenic. Arch. Environ. Contam. Toxicol. 24, 187, 1999.