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Mercury levels and trends in fish and mussels from German surface waters – comparison with the EQS as specified in Directive 2008/105/EC

by

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1. Initial situation

Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 (EQS Directive) requires compliance with an environmental quality standard of 20 µg/kg wet weight for mercury and mercury compounds in biota. At the same time, the most appropriate indicator must be selected among fish, molluscs and crustaceans. This threshold value serves the protection of higher organisms (mammals and raptors) against poisoning via the food chain ("secondary poisoning"). The development of the environmental quality standard (hereafter: EQS) is based on the methodological framework put forward by Lepper (2005) [1]. The substance safety sheet for mercury and its compounds, which documents the bases for the development of an EQS, can be obtained at the CIRCA Website [2].

Threshold values for food, as the maximum concentration of mercury in fish, are for many fish species at 1.0 mg/kg wet weight[1] fifty times higher than the EQS, and for all other fish still 25 times higher at 0.5 mg/kg wet weight. The differences are explained by the fact that, for example otters and ospreys feed almost exclusively on fish, while humans consume comparatively and proportionately much less fish. Dietary habits are reflected in the levels of threshold values.

In this report, present mercury concentrations in biota from German inland waters are discussed in detail. Whereas the EQS for biota is extensively and noticeably exceeded in fish, food threshold values for mercury in fish are generally adhered to, though even here limits are exceeded in isolated cases. Recourse is made to analysis findings of the German Environmental Specimen Bank *(Umweltprobenbank des Bundes (UPB))* as a statistical basis. On the basis of such analyses recommendations are made for further action.

2. Investigation programme of the German Environmental Specimen Bank (GESB)

The GESB has collected data for more than 15 years on mercury in biota from various rivers and a lake as well as from the coastal waters of the Baltic Sea and the North Sea in Germany.

In inland water bodies the bream (carp bream, *Abramis brama*) is sampled, namely in the age group of 8 to 12 years. As a stenoecious species that restricts itself to a particular habitat, and also due to its wide distribution, the bream serves as a highly appropriate bioindicator in rivers and lakes. As result of its regional utilization as a food fish, there is also a direct connection to the human food chain. Mercury is analysed in the muscle tissue.

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[1] Anglerfish, spined loach, perch, blue ling, skipjack (tuna), true eel, orange roughy, roundnose grenadier, Atlantic halibut, marlin, pike, plain bonito, skates/rays, red/rose fish, Pacific sailfish, cutlassfish, shark, escolar, snake mackerel, common surgeon, swordfish, tuna

The GESB also investigates zebra mussels (*Dreissena polymorpha*) in inland waters. The zebra mussel serves as a food source for fish; for instance, for the bream. It itself lives off microorganisms that it filters from water, and is thus one of the group of primary consumers. On account of their wide distribution and extensive exposure to pollutants, it is a frequently applied organism for passive and active monitoring. The whole soft body of adult zebra mussels is analysed in their second year of life, when they have a shell length of about 15 to 25 mm.

GESB sampling in inland waters comprises a total of 17 sampling areas. Of these, five are in the River Elbe, four in the River Rhine, two in the River Saar, and one each in the Elbe tributaries Saale and Mulde, as well as, since 2002, three in the River Danube. In addition, Belauer Lake (Bornhöved Lake District, in the State of Schleswig-Holstein) is investigated as an unpolluted reference water body (Figure 1).

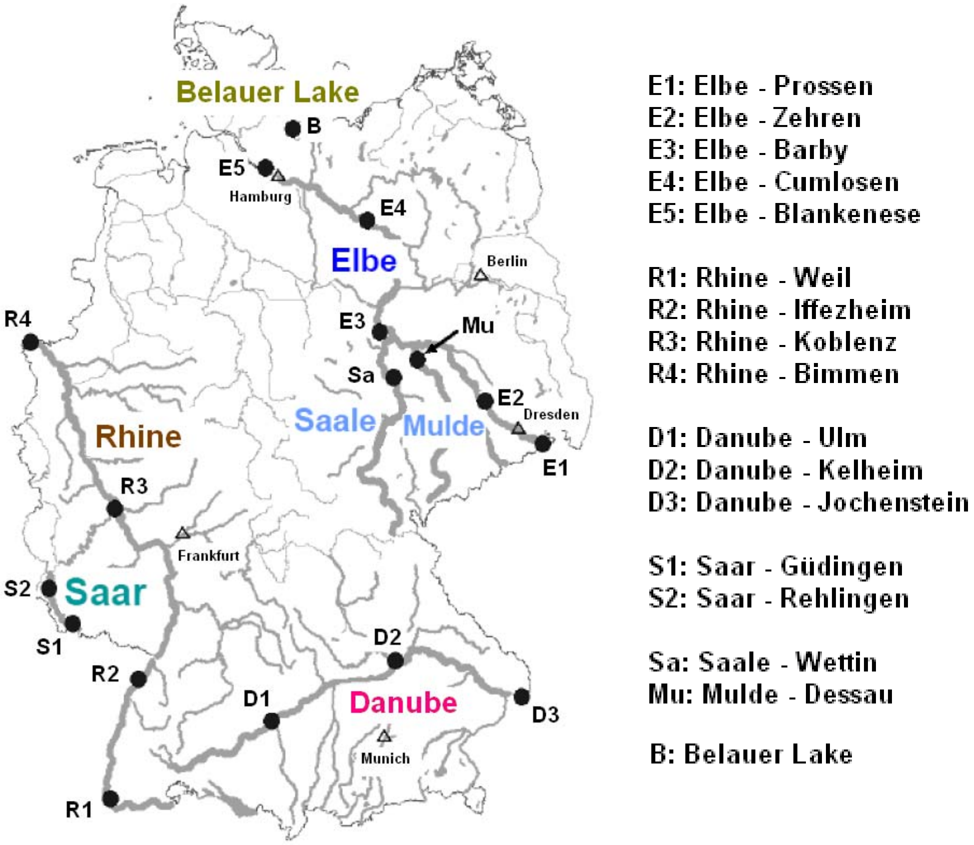


Figure 1: Sampling areas of the German Environmental Specimen Bank (GESB) in inland waters. Source of the diagram: Fraunhofer Institute for Molecular Biology and Applied Ecology (IME), Schmallenberg

3. Mercury concentrations in bream

Mercury concentrations in sampled bream show, in part, noticeable differences between individual sampling sites. Measured concentrations for all samples are, however, distinctly above the EQS of 20 µg/kg wet weight, even at the refernce site. In Figure 2, findings from Belauer Lake and the rivers Saar, Rhine and Danube for the period from 1994 (commencement of investigations) to 2009 are compared. Original GESB data in µg/kg dry weight has been converted with the factor of 0.2 into wet weight (hereafter: ww) (water content of the tissue: 80%).

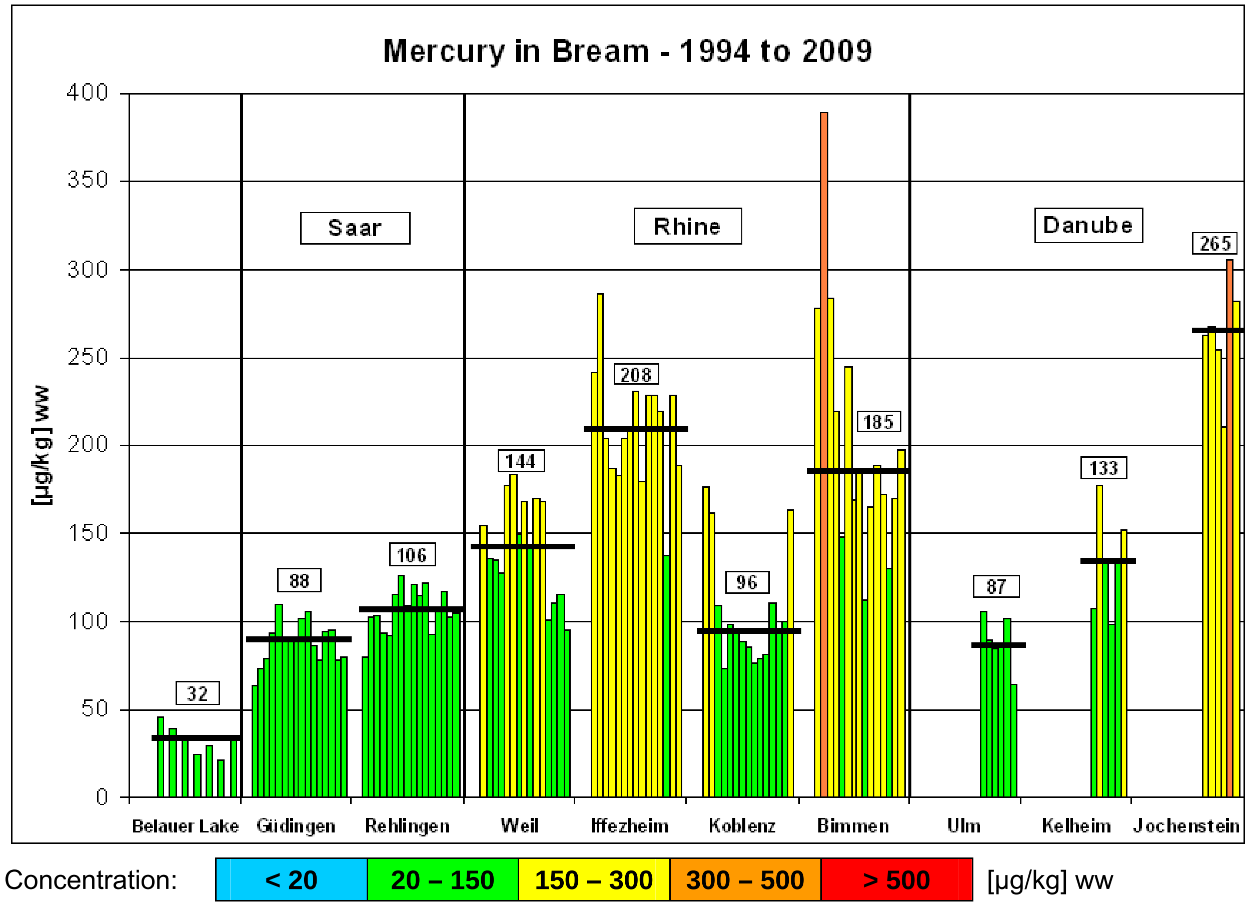


Figure 2: Mercury concentrations (µg/kg wet weight) in bream from Belauer Lake and the rivers Saar, Rhine and Danube in the period 1994 to 2009. Horizontal bars and framed figures = median. Data source: German Environmental Specimen Bank (GESB)

Whether, and to what extent the observed differences in concentration between individual sampling sites are significant, can be examined by means of statistical tests. For this purpose, the individual data series were compared on the basis of the non-parametric Mann-Whitney U test (a "robust" test that requires no particular data distribution) and the classic Student's *t*-test (that, in principle, requires normal distribution of data, yet responds quite insensitively to deviations). The results are shown in Table 1. It is shown that differences in concentration between individual sampling points are, in part, highly significant, which means that the statistical probability of a difference is greater than 99.9%; whereby the results of both tests concur.

Table 1: Statistical probability of differences in concentration between the individual data series "Mercury in bream – 1994 to 2009“ (Figure 2), based on the non-parametric Mann-Whitney U test (two-sided) and a classic *t*-test (independent unpaired samples, two-sided); in each case upper row: U test, lower row: *t*-test

P [%]	**Güdingen**	**Rehlingen**	**Weil**	**Iffez-heim**	**Koblenz**	**Bimmen**	**Ulm**	**Kelheim**	**Jochen-stein**
Belauer Lake	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.,9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**
Güdingen		**> 99.9** **> 99.9**	**> 99,9** **> 99.9**	**> 99.9** **> 99.9**	< 95 **> 95**	**> 99.9** **> 99.9**	< 95 < 95	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**
Rehlingen	**> 99.9** **> 99.9**		**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	< 95 < 95	**> 99.9** **> 99.9**	**> 95** **> 95**	**> 95** **> 99**	**> 99.9** **> 99.9**
Weil	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**		**> 99.9** **> 99.9**	**> 99** **> 99**	**> 99** **> 99**	**> 99.9** **> 99.9**	< 95 < 95	**> 99.9** **> 99.9**
Iffezheim	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**		**> 99.9** **> 99.9**	< 95 < 95	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99** **> 99**
Koblenz	< 95 **> 95**	< 95 < 95	**> 99** **> 99**	**> 99.9** **> 99.9**		**> 99.9** **> 99.9**	< 95 < 95	< 95 < 95	**> 99.9** **> 99.9**
Bimmen	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99** **> 99**	< 95 < 95	**> 99.9** **> 99.9**		**> 99.9** **> 99.9**	**> 95** **> 95**	**> 95** < 95
Ulm	< 95 < 95	**> 95** **> 95**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	< 95 < 95	**> 99.9** **> 99.9**		**> 99** **> 99**	**> 99** **> 99.9**
Kelheim	**> 99.9** **> 99.9**	**> 95** **> 99**	< 95 < 95	**> 99.9** **> 99.9**	< 95 < 95	**> 95** **> 95**	**> 99** **> 99**		**> 99** **> 99.9**
Jochenstein	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99.9** **> 99.9**	**> 99** **> 99**	**> 99.9** **> 99.9**	**> 95** < 95	**> 99** **> 99.9**	**> 99** **> 99.9**	

Classification:	**not significant** **< 95%**	**significant** **> 95%**	**very significant** **> 99%**	**highly significant** **> 99.9%**

For comparison of results from the Elbe and its tributaries Saale/Mulde, the data were for the time being limited to the period from the year 2000 to 2009 (Figure 3), since at these sites there was a strong temporal trend in prior years that will be separately discussed. It can be seen that average concentrations of mercury in bream from the rivers Elbe and Saale/Mulde – with the exception of the Blankenese sampling point – are distinctly above those in bream from the rivers Rhine and Saar.

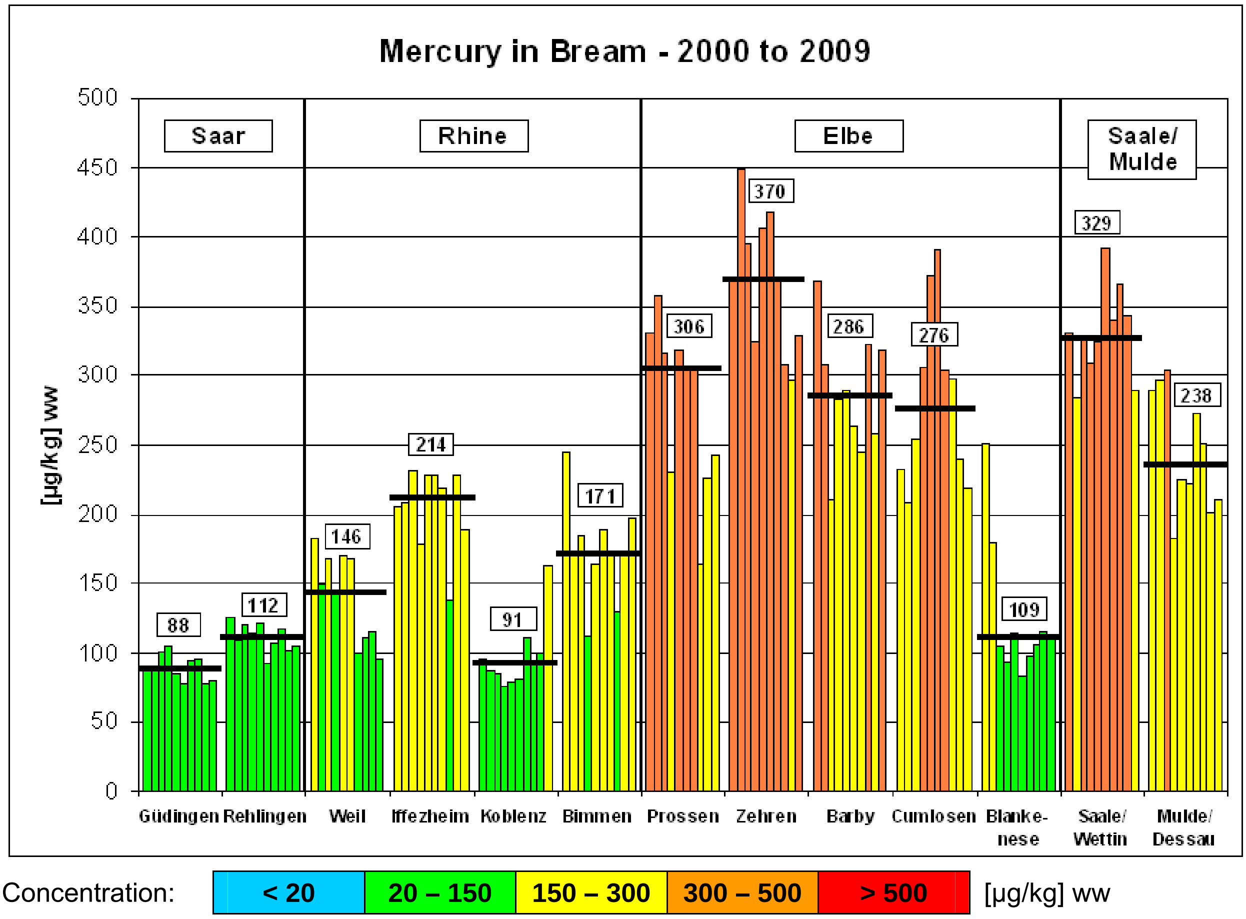


Figure 3: Mercury concentrations (µg/kg wet weight) in bream from the rivers Saar, Rhine, Elbe und Saale/Mulde for the period 2000 to 2009. Horizontal bars and framed figures = median. Data source: German Environmental Specimen Bank (GESB)

The significance of individual differences in concentration can be examined with the aid of the above-mentioned statistical tests (Table 2). Differences in concentration between individual sampling points are for the most part highly significant.

Table 2: Statistical probability of differences in concentration between the individual data series "Mercury in bream – 2000 to 2009“ (Figure 3), based on the non-parametric Mann-Whitney U test (two-sided) and a classic *t*-test (independent unpaired samples, two-sided); in each case upper row: U test, lower row: *t*-test

P [%]	Rehlin-gen	Weil	Iffez-heim	Koblenz	Bimmen	Prossen	Zehren	Barby	Cumlo-sen	Blanke-nese	Saale/ Wettin	Mulde/ Dessau
Güdin-gen	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 95	> 99.9 > 99.9	> 99.9 > 99.9
Rehlin-gen		< 95 > 95	> 99.9 > 99.9	> 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9
Weil	< 95 > 95		> 99.9 > 99.9	> 99 > 99	> 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9
Iffez-heim	> 99.9 > 99.9	> 99.9 > 99.9		> 99.9 > 99.9	> 95 > 95	> 99 > 99	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	> 99 > 99.9	> 99.9 > 99.9	< 95 > 95
Koblenz	> 95 < 95	> 99 > 99	> 99.9 > 99.9		> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9
Bimmen	> 99.9 > 99.9	> 95 > 95	> 95 > 95	> 99.9 > 99.9		> 99 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9
Prossen	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	> 99.9 > 99.9	> 99 > 99.9		> 99 > 99	< 95 < 95	< 95 < 95	> 99.9 > 99.9	< 95 > 95	< 95 < 95
Zehren	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99		> 99 > 99	> 99 > 99	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9
Barby	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99 > 99		< 95 < 95	> 99.9 > 99.9	> 95 > 95	< 95 < 95
Cumlo-sen	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99 > 99	< 95 < 95		> 99.9 > 99.9	< 95 > 95	< 95 < 95
Blanke-nese	< 95 < 95	< 95 < 95	> 99 > 99.9	> 95 < 95	> 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9		> 99.9 > 99.9	> 99.9 > 99.9
Saale/ Wettin	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 > 95	< 95 < 95	> 95 > 95	< 95 > 95	> 99.9 > 99.9		> 99.9 > 99.9
Mulde/ Dessau	> 99.9 > 99.9	> 99.9 > 99.9	< 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	< 95 < 95	< 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9	

Classification:	not significant	significant	very significant	highly significant
	< 95%	**> 95%**	**> 99%**	**> 99.9%**

In summary, it can be said that mercury concentrations in bream from German rivers presently lie between 100 and 400 µg/kg wet weight, and therefore exceed the EQS for biota by a factor of 5 to 20 (Table 3). The lowest mercury concentrations among GESB samples are seen in bream from Belauer Lake, the reference water body, with about 20 to 50 µg/kg ww, thereby just missing the EQS. The highest mercury concentrations were found in bream from the rivers Elbe and Saale, with more than 300 µg/kg ww.

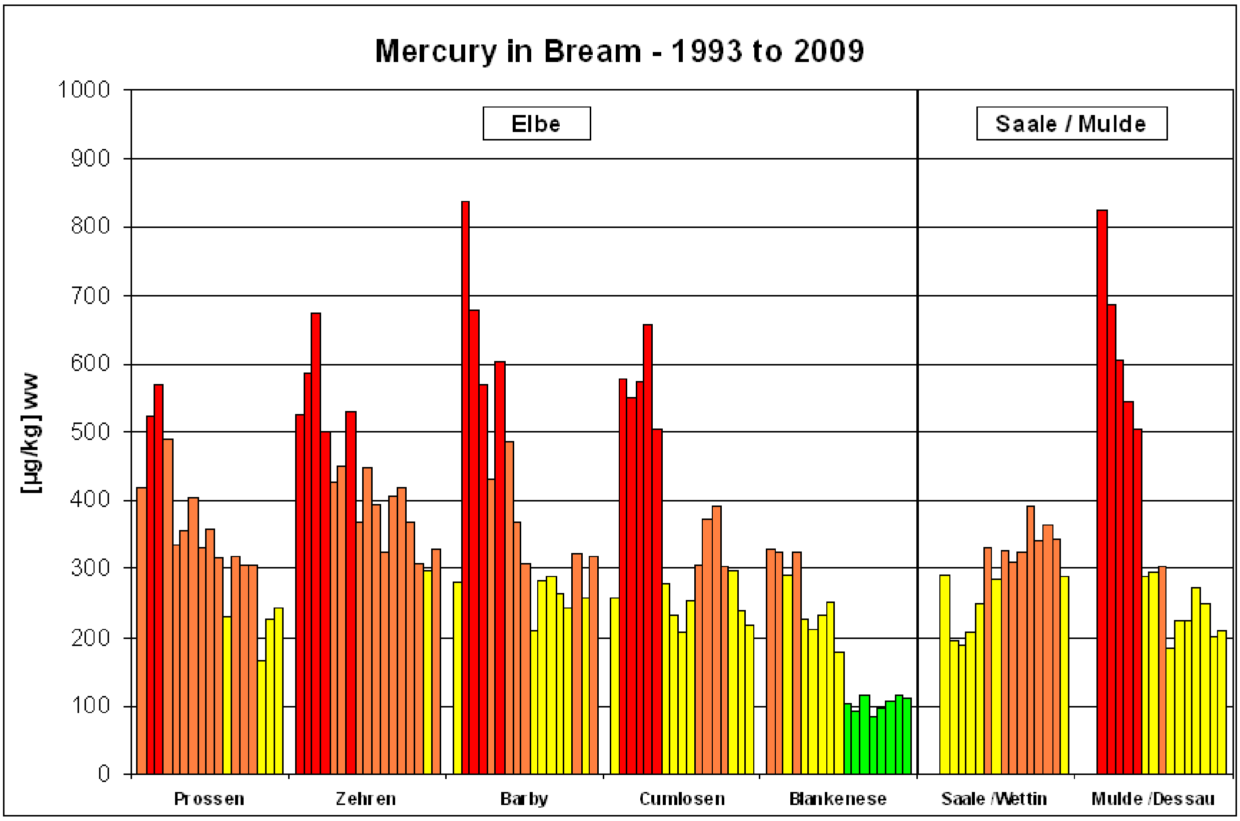
The observed differences in concentration in bream from individual water bodies and sites are, in part, statistically highly significant, which points to differences in the pollution level of water bodies that in turn are reflected in the mercury levels of the breams. The mercury concentrations in bream, however, do not correlate in all cases with mercury levels measured in other compartments, for example, suspended particulate matter (Table 7, page 14; comparison with concentrations in SPM).

Table 3: Summary of mercury concentrations (µg/kg wet weight) in bream from 17 inland water sampling areas of the German Environmental Specimen Bank (GESB) in the period from 2000 to 2009

Water	**Concentration range for Hg in bream in [µg/kg] ww**	**Concentrations at individual sites in [µg/kg] ww**
Belauer Lake	20 – 50	--
Saar	≈ 100	S1 – Güdingen: ≈ 100 S2 – Relingen: ≈ 100
Rhine	100 – 250	R1 – Weil: 100 – 150 R2 – Iffezheim: 200 – 250 R3 – Koblenz: ≈ 100 R4 – Bimmen: 150 – 200
Danube	100 – 300	D1 – Ulm: ≈ 100 D2 – Kelheim: 100 – 150 D3 –Jochenstein: 250 – 300
Elbe	100 – 400	E1 – Prossen: 250 – 350 E2 – Zehren: 300 – 400 E3 – Barby: 250 – 350 E4 – Cumlosen: 200 – 350 E5 – Blankenese: ≈ 100
Saale/Mulde	200 – 350	Sa – Saale /Wettin: 300 – 350 Mu – Mulde /Dessau: 200 – 300

Concentration:	**< 20**	**20 – 150**	**150 – 300**	**300 – 500**	**> 500**	[µg/kg] ww

Mercury concentrations in bream from the rivers Elbe and Mulde show, from 1993, a marked decrease to 30 to 50% of the initial concentrations (Figure 4). In the Saale at Wettin, on the other hand, there is an increasing trend by a factor of just less than two.



Concentration: < 20 | 20 – 150 | 150 – 300 | 300 – 500 | > 500 [µg/kg] ww

Figure 4: Mercury concentrations (µg/kg wet weight) in bream from the rivers Elbe and Saale/Mulde in the period 1993 to 2009. Data source: German Environmental Specimen Bank (GESB)

In order to determine whether changes in concentrations of mercury in bream from the rivers Elbe and Saale/Mulde are statistically significant, the non-parametric Mann-Kendall trend test was carried out on every data series (Table 4). There are decreasing trends in mercury levels in the rivers Elbe and Mulde with a statistical probability of 99% at all stations (at site E4 (Cumlosen), however, the probability is just 95%). On the other hand, in the Saale at Wettin station, there is an increasing trend in mercury concentrations with 99% probability. In the rivers Saar, Rhine and Danube no trends in mercury concentrations are detectable except at sampling site R4 (Bimmen), where there is a decreasing trend with 95% probability.

A trend with 95% probability is categorized as significant in the German Ordinance on the Protection of Surface Waters.

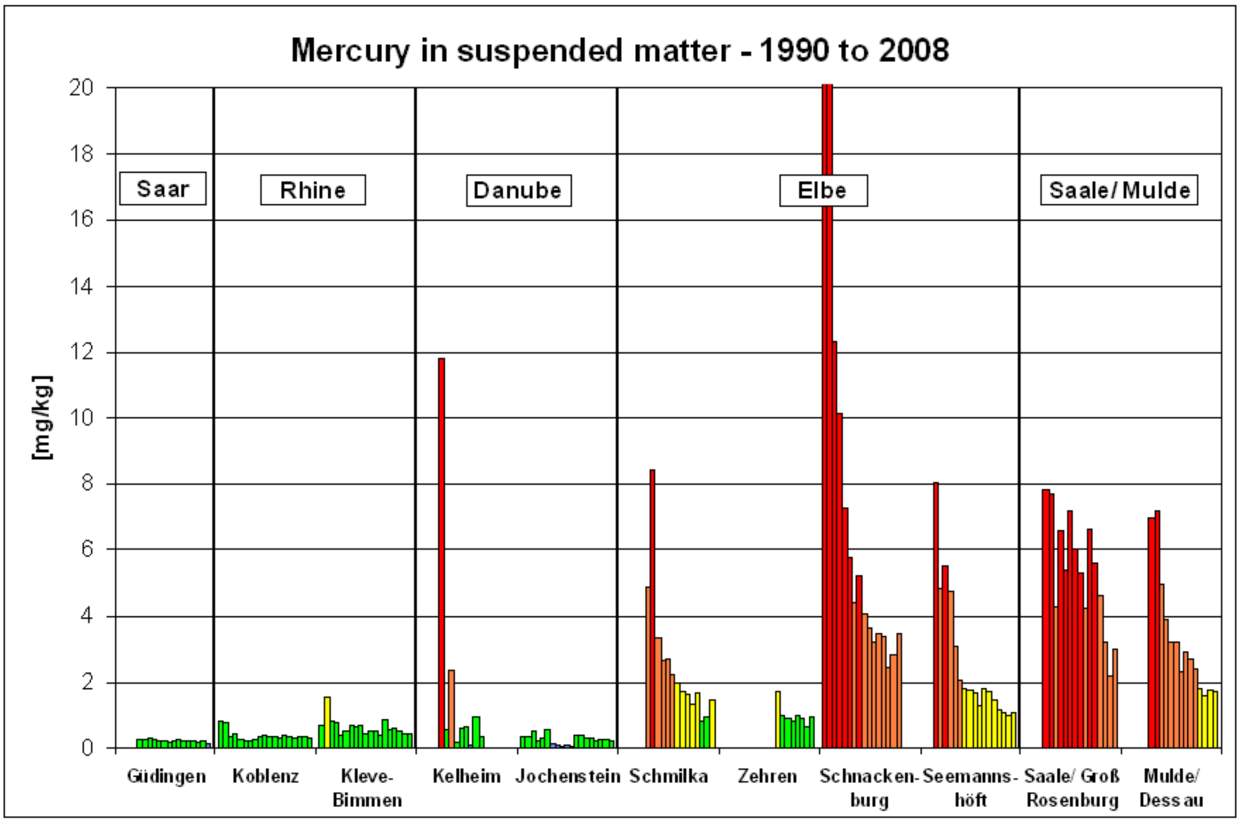
The significant trends in mercury concentrations in bream from the rivers Elbe and Saale/Mulde point to changes in pollution levels in these waters.

Table 4: Statistical probability of trends in the individual data series "Mercury in bream – 1993 to 2009" (Figures 2 and 4), based on the non-parametric Mann-Kendall trend test (one-sided)

Site	Statistical probability P for a trend
Belauer Lake	decreasing: 95%
Saar – S1 (Güdingen)	no trend
Saar – S2 (Rehlingen)	no trend
Rhine – R1 (Weil)	no trend
Rhine – R2 (Iffezheim)	no trend
Rhine – R3 (Koblenz)	no trend
Rhine – R4 (Bimmen)	decreasing: 95%
Danube – D1 (Ulm)	no trend
Danube – D2 (Kelheim)	no trend
Danube – D3 (Jochenstein)	no trend
Elbe – E1 (Prossen)	decreasing: 99%
Elbe – E2 (Zehren)	decreasing: 99%
Elbe – E3 (Barby)	decreasing: 99%
Elbe – E4 (Cumlosen)	decreasing: 95%
Elbe – E5 (Blankenese)	decreasing: 99%
Saale – Wettin	increasing: 99%
Mulde – Dessau	decreasing: 99%

4. Mercury concentrations in suspended particulate matter (SPM)

In order to examine the extent to which significant trends in mercury concentrations in bream correlate with pollution or changes in pollution in other environmental compartments, biota results were compared with mercury concentrations in suspended particulate matter (SPM) from the sampled rivers. In the Elbe, for comparison of mercury levels in bream from E1 (Prossen, river km 13) SMP concentrations from sampling site Schmilka (river km 4) were employed, while for mercury levels in bream from E4 (Cumlosen, river km 470) and E5 (Blankenese, river km 634) SPM results from Schnackenburg (river km 474) and from Seemannshöft (river km 629) were used, respectively. For the Saale, mercury levels in bream from site Wettin (about 70 km from the confluence of the rivers Saale and Elbe) were compared with mercury levels in SPM collected at Groß Rosenburg where the two rivers merge (Figure 5).



Concentration: < 0.2 | 0.2 – 1 | 1 – 2 | 2 – 5 | > 5 [mg/kg]

Figure 5: Mercury concentrations (mg/kg dry weight) in suspended particulate matter from the rivers Saar, Rhine, Danube, Elbe and Saale/Mulde in the period 1990 to 2008. Data source: Compilation of the Federal Environment Agency based on data from the Joint Working Group on Water of the Federal Government and the Federal *Länder* (LAWA)

Mercury levels in SPM from the rivers Elbe and Saale/Mulde decrease from 1990 to 2008, while concentrations in SPM from the rivers Saar, Rhine and Danube show no clear trends. In the rivers Elbe and Saale/Mulde, mercury concentrations in suspended matter between 1993/94 – from this point in time measurements are available for almost all sites – and 2008 decline from about 5 to 10 mg/kg to about 1 to 3 mg/kg. This is equivalent to a decrease in concentrations at individual sites of 60 to 80%. In the rivers Saar, Rhine and Danube, mercury concentrations in SPM are below 1 mg/kg with few exceptions in the whole period.

The significance of mercury concentration changes was again examined with the Mann-Kendall trend test (Table 5). It was confirmed that at the sampling points along the rivers Elbe (with the exception of site E2 (Zehren), where measurements only commenced in 2001) and Saale/Mulde mercury concentrations in SPM show decreasing trends with 99% probability. In the rivers Rhine and Danube, on the other hand, no trends are ascertainable, with the exception of site R4 (Kleve-Bimmen) where there is 95% probability of a decreasing trend. In the Saar, at Güdingen (S1), there is a significantly decreasing trend at a very low concentration level.

Table 5: Statistical probability of trends in the individual data series "Mercury in suspended matter – 1990 to 2008“ (Figure 5), based on the non-parametric Mann-Kendall trend test (one-sided)

Site	Statistical probability P for a trend
Saar – S1 (Güdingen)	decreasing: 99%
Rhine – R3 (Koblenz)	no trend
Rhine – R4 (Kleve-Bimmen)	decreasing: 95%
Danube – D2 (Kelheim)	no trend
Danube – D3 (Jochenstein)	no trend
Elbe – Schmilka	decreasing: 99%
Elbe – E2 (Zehren)	no trend
Elbe – Schnackenburg	decreasing: 99%
Elbe – Seemannshöft	decreasing: 99%
Saale – Groß Rosenburg	decreasing: 99%
Mulde – Dessau	decreasing: 99%

It should be noted that the observed decrease in mercury concentrations in bream from the rivers Elbe and Mulde between 1993 and 2009 corresponds well with analogous decrease in mercury concentrations in SPM in these waters. The sole exception is the Saale, where at the Wettin sampling point, in contrast to the general trend, there is an increase in mercury concentrations in bream but a declining trend in SPM.

All in all, the good correlation between mercury levels in bream and SPM can be regarded as a clear indication that the bream is a suitable species for montoring changes in mercury concentrations in inland waters.

Mercury concentrations in SPM in the rivers Saar, Rhine and Danube collected in the period 2000 to 2008 are invariably below 1 mg/kg, while those in SPM from the Elbe range from 1 to 3 mg/kg. The highest mercury concentrations in SPM are found in the Saale, at Groß Rosenburg, with average concentration of more than 4 mg/kg at the beginning of the study period, however with a decreasing trend in mercury levels to 2 to 3 mg/kg in the last years (Figure 6).

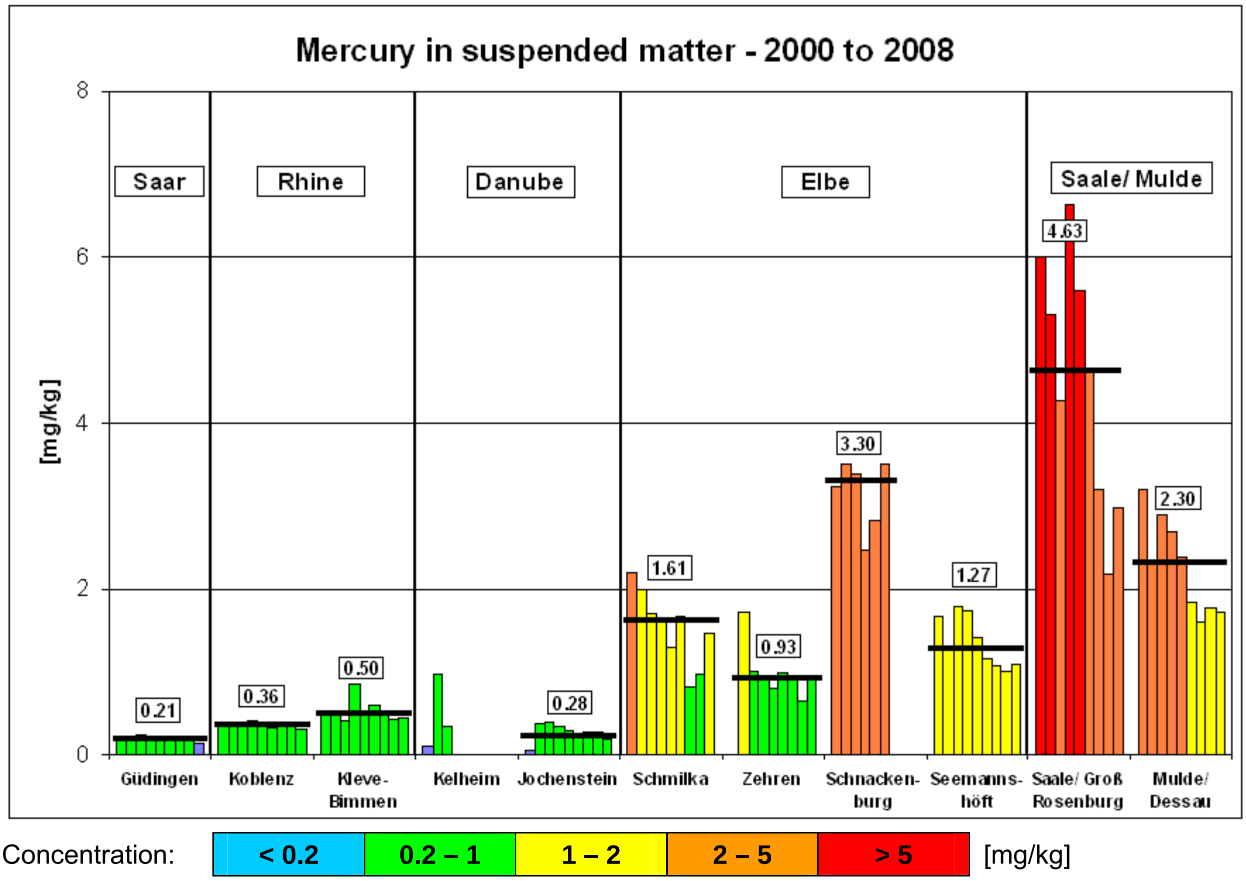


Figure 6: Mercury concentrations (mg/kg dry weight) in suspended particulate matter from the rivers Saar, Rhine, Danube, Elbe and Saale/Mulde in the period 2000 to 2008. Horizontal bars and framed figures = median. Data source: Compilation of the Federal Environment Agency based on the basis from the Joint Working Group on Water of the Federal Government and the Federal *Länder* (LAWA)

The significance of differences in concentrations in suspended matter between individual sampling points is for the most part high (Table 6).

Table 6: Statistical probability of differences in concentration between the individual data series "Mercury in suspended matter – 2000 to 2008“ (Figure 6), based on the non-parametric Mann-Whitney U test (two-sided) and a classic *t*-test (independent unpaired samples, two-sided); in each case upper row: U test, lower row: *t*-test

P [%]	Güdingen	Koblenz	Kleve-Bimmen	Jochenstein	Schmilka	Zehren	Schnackenburg	Seemannshöft	Saale/ Gr. Rosenb.	Mulde/ Dessau
Güdingen		> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Koblenz	> 99,9 > 99,9		> 99.9 > 99	< 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Kleve-Bimmen	> 99,9 > 99,9	> 99.9 > 99		> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Jochenstein	< 95 < 95	< 95 > 95	> 99.9 > 99.9		> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Schmilka	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9		< 95 > 95	> 99.9 > 99.9	< 95 < 95	> 99.9 > 99.9	> 99 > 99
Zehren	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99	> 99.9 > 99.9	< 95 > 95		> 99.9 > 99.9	> 99 > 95	> 99.9 > 99.9	> 99.9 > 99.9
Schnackenburg	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9		> 99.9 > 99.9	< 95 > 95	> 99 > 99
Seemannshöft	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	> 99 > 95	> 99.9 > 99.9		> 99.9 > 99.9	> 99 > 99.9
Saale/ Groß Rosenburg	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 > 95	> 99.9 > 99.9		> 99 > 99.9
Mulde/ Dessau	> 99,9 > 99,9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	> 99.9 > 99.9	> 99 > 99	> 99 > 99.9	> 99 > 99.9	

Classification:	not significant < 95%	significant > 95%	very significant > 99%	highly significant > 99.9%

Mercury concentrations in SPM and in bream are compared for the period 2000 to 2008/09 in Table 7.

Table 7: Comparison of mercury concentrations in suspended particulate matter (SPM) and bream for the period 2000 to 2008/09 at different sites on the rivers Saar, Rhine, Danube, Elbe, Saale and Mulde

Site	Hg concentration in SPM	Hg concentration in bream
Saar – S1 (Güdingen)	0.2 – 0.3 mg/kg	≈ 100 µg/kg ww
Rhine – R1 (Weil)	≈ 0.2 mg/kg*	100 – 150 µg/kg ww
Rhine – R2 (Iffezheim)	≈ 0.4 mg/kg*	200 – 250 µg/kg ww
Rhine – R3 (Koblenz)	0.3 – 0.5 mg/kg	≈ 100 µg/kg ww
Rhine – R4 (Bimmen)	0.5 – 1.0 mg/kg	150 – 200 µg/kg ww
Danube – D3 (Jochenstein)	0.2 – 0.5 mg/kg	250 – 300 µg/kg ww
Elbe – E1 (Prossen)	1 – 2 mg/kg (Schmilka)	250 – 350 µg/kg ww
Elbe – E2 (Zehren)	1 – 2 mg/kg	300 – 400 µg/kg ww
Elbe – E4 (Cumlosen)	3 – 4 mg/kg (Schnackenburg)	200 – 350 µg/kg ww
Elbe – E5 (Blankenese)	1 – 2 mg/kg (Seemannshöft)	≈ 100 µg/kg ww
Saale – Wettin	3 – 6 mg/kg (Groß Rosenburg)	300 – 350 µg/kg ww
Mulde – Dessau	2 – 3 mg/kg	200 – 300 µg/kg ww

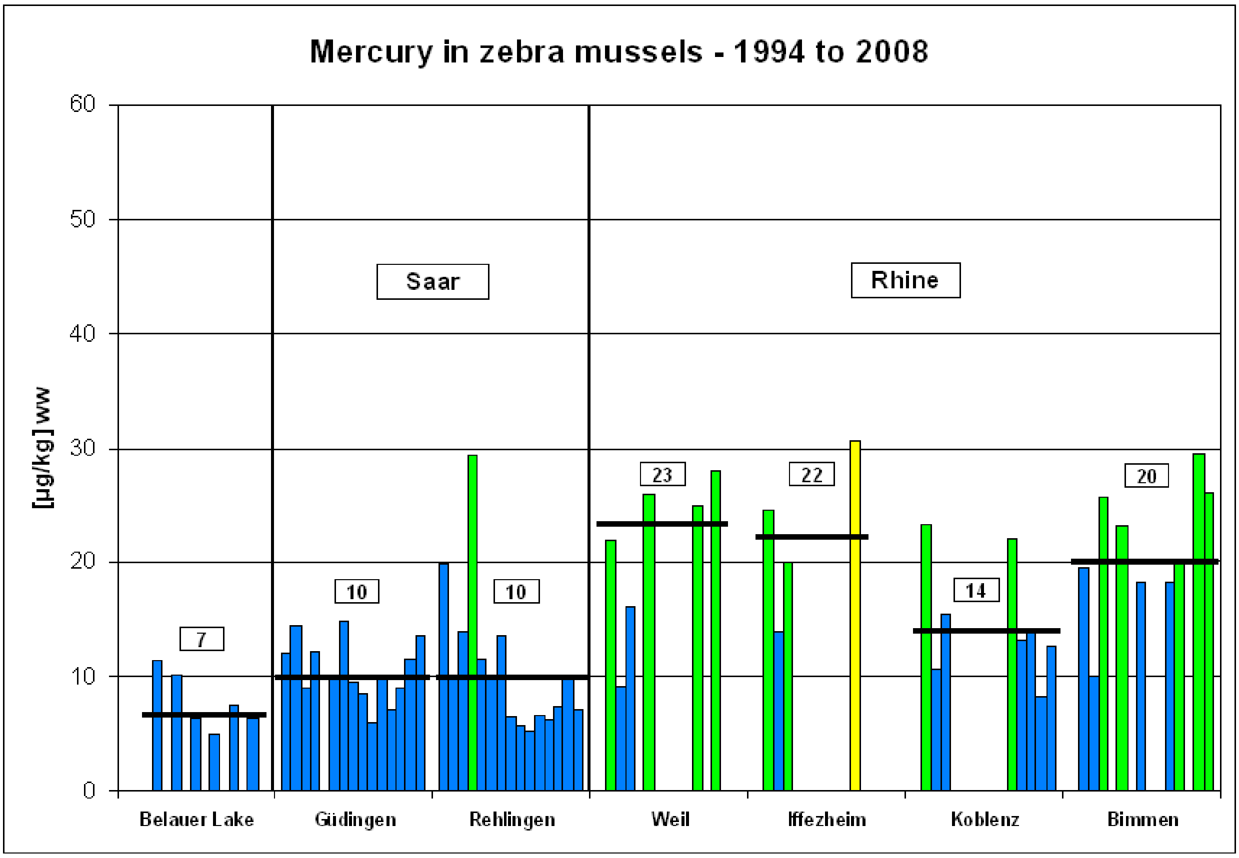
* Data source: International Commission for the Protection of the Rhine (ICPR) / German Rhine monitoring programme (DUR)

The following correlations can be established between mercury concentrations in SPM and in bream: Low mercury concentrations in SPM in the rivers Saar and Rhine (below 1 mg/kg) correspond with low to medium levels in bream (100 to 200 µg/kg ww). The high concentrations in SPM in the rivers Elbe and Saale/Mulde (1 to 6 mg/kg) are reflected in increased mercury concentrations in bream (200 to 400 µg/kg ww). Exceptions thereof are the raised mercury concentrations in SPM from Seemannshöft, which compare less well with the relatively low concentrations in bream from Blankenese (E5), and the low concentrations in SPM in the Danube at D3 (Jochenstein) and in the Rhine at R2 (Iffezheim), which do not correlate with the relatively high levels measured in bream.

5. Mercury concentrations in zebra mussels

The zebra mussel is besides the bream the second biota species that is sampled in inland waters and analysed by the GESB. Original GESB data in µg/kg dry weight has been converted by the factor of 0.15 into wet weight (ww) assuming an average water content of the tissue of 85%.

Concentrations of mercury in zebra mussels lie between 10 and 50 µg/kg ww. They are thus around 10 per cent of those in bream and exceed the EQS for biota at the most by a factor of 2.5. More than half of measured concentrations comply with the EQS of 20 µg/kg ww (Figures 7 and 8).



Concentration: < 20 | 20 – 30 | 30 – 50 | 50 – 100 | > 100 [µg/kg] ww

Figure 7: Mercury concentrations (µg/kg wet weight) in zebra mussels from Belauer Lake, the rivers Saar and Rhine in the period 1994 to 2008. Horizontal bars and framed figures = median. Data source: German Environmental Specimen Bank (GESB)

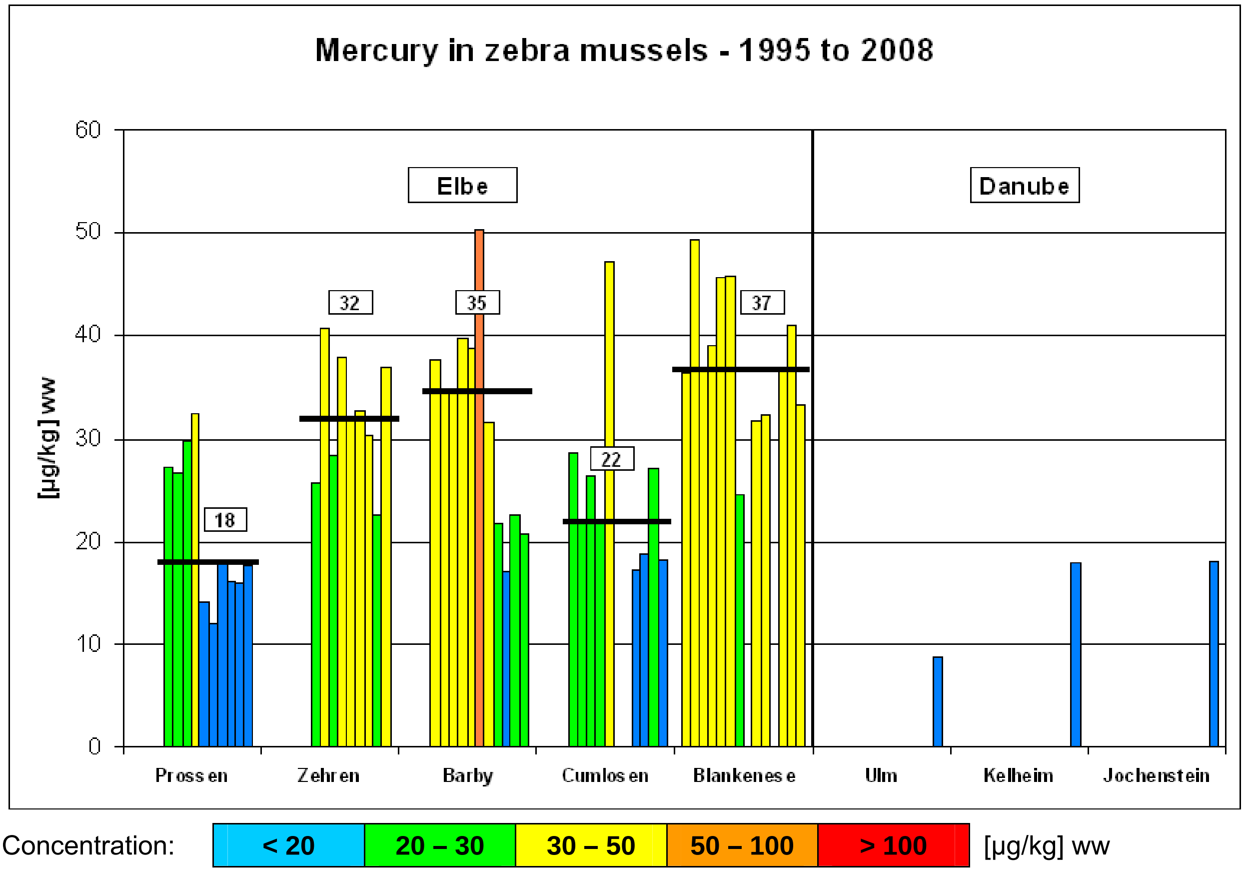


Figure. 8: Mercury concentrations (µg/kg wet weight) in zebra mussels from the rivers Elbe and Danube in the period 1995 to 2008. Horizontal bars and framed figures = median. Data source: German Environmental Specimen Bank (GESB)

Statistical analyses of the significance of differences in concentration and trends were carried out in the manner already described with regard to bream (Tables 8 and 9).

Table 8: Statistical probability of differences in concentration between the individual data series "Mercury in zebra mussels – 1994 to 2008 or 1995 to 2008" (Figures 7 and 8), based on the non-parametric Mann-Whitney U test (two-sided) and a classic *t*-test (independent unpaired samples, two-sided); in each case upper row: U test, lower row: *t*-test

P [%]	Güdin-gen	Rehlin-gen	Weil	Iffez-heim	Koblenz	Bimmen	Prossen	Zehren	Barby	Cumlo-sen	Blanke-nese
Belauer Lake	< 95 > 95	< 95 < 95	> 99 > 99	> 99 > 99	> 99 > 99	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Güdin-gen		< 95 < 95	> 99 > 99.9	> 99 > 99.9	> 95 > 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Rehlin-gen	< 95 < 95		> 95 > 99	> 99 > 99	> 95 < 95	> 99 > 99.9	> 99.9 > 99	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9
Weil	> 99 > 99.9	> 95 > 99		< 95 < 95	< 95 < 95	< 95 < 95	< 95 < 95	> 99 > 99	< 95 > 95	< 95 < 95	> 99.9 > 99.9
Iffez-heim	> 99 > 99.9	> 99 > 99	< 95 < 95		< 95 < 95	< 95 < 95	< 95 < 95	< 95 > 95	< 95 < 95	< 95 < 95	> 99 > 99
Koblenz	> 95 > 95	> 95 < 95	< 95 < 95	< 95 < 95		> 95 > 95	> 95 < 95	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 95	> 99.9 > 99.9
Bimmen	> 99.9 > 99.9	> 99 > 99.9	< 95 < 95	< 95 < 95	> 95 > 95		< 95 < 95	> 99 > 99	> 95 > 95	< 95 < 95	> 99.9 > 99.9
Prossen	> 99.9 > 99.9	> 99.9 > 99	< 95 < 95	< 95 < 95	> 95 < 95	< 95 < 95		> 99 > 99	> 99 > 95	< 95 < 95	> 99.9 > 99.9
Zehren	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	< 95 > 95	> 99.9 > 99.9	> 99 > 99	> 99 > 99		< 95 < 95	> 95 < 95	< 95 < 95
Barby	> 99.9 > 99.9	> 99.9 > 99.9	< 95 > 95	< 95 < 95	> 99.9 > 99.9	> 95 > 95	> 99 > 95	< 95 < 95		< 95 < 95	< 95 < 95
Cumlo-sen	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	< 95 < 95	> 99 > 95	< 95 < 95	< 95 < 95	> 95 < 95	< 95 < 95		> 99 > 99
Blanke-nese	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	> 99 > 99	> 99.9 > 99.9	> 99.9 > 99.9	> 99.9 > 99.9	< 95 < 95	< 95 < 95	> 99 > 99	

Classification:	**not significant** **< 95%**	**significant** **> 95%**	**very significant** **> 99%**	**highly significant** **> 99.9%**

Table 9: Statistical probability of trends in the individual data series "Mercury in zebra mussels – 1994 to 2008 or 1995 to 2008“ (Figures 7 and 8), based on the non-parametric Mann-Kendall trend test (one-sided)

Site	Statistical probability P for a trend
Belauer Lake	no trend
Saar – S1 (Güdingen)	no trend
Saar – S2 (Rehlingen)	decreasing: 95%
Rhine – R1 (Weil)	no trend
Rhine – R2 (Iffezheim)	no trend
Rhine – R3 (Koblenz)	no trend
Rhine – R4 (Bimmen)	no trend
Elbe – E1 (Prossen)	no trend
Elbe – E2 (Zehren)	no trend
Elbe – E3 (Barby)	decreasing: 95%
Elbe – E4 (Cumlosen)	no trend
Elbe – E5 (Blankenese)	no trend

The lowest mercury concentrations – 5 to 10 µg/kg ww – are found in zebra mussels from Belauer Lake, the reference water body, and therefore comply with the EQS for biota. The highest mercury concentrations – 20 to 50 µg/kg ww – are found in zebra mussels from the River Elbe (Table 10).

Table 10: Summary of mercury concentrations (µg/kg wet weight) in zebra mussels from the 17 inland water sampling areas of the German Environmental Specimen Bank (GESB) in the period 1994/95 to 2008

Water	Concentration range for Hg in zebra mussels in [µg/kg] ww	Concentrations at individual sites in [µg/kg] ww
Belauer Lake	5 – 10	--
Saar	5 – 20	S1 – Güdingen: 5 – 15 S2 – Relingen: 5 – 20
Rhine	10 – 30	R1 – Weil: 15 – 30 R2 – Iffezheim: 15 – 30 R3 – Koblenz: 10 – 20 R4 – Bimmen: 20 – 30
Danube	10 – 20	D1 – Ulm: ≈ 10 D2 – Kelheim: ≈ 20 D3 – Jochenstein: ≈ 20
Elbe	20 – 50	E1 – Prossen: 15 – 30 E2 – Zehren: 25 – 40 E3 – Barby: 20 – 40 E4 – Cumlosen: 20 – 40 E5 – Blankenese: 25 – 50

Concentration:	< 20	20 – 30	30 – 50	50 – 100	> 100	[µg/kg] ww

Mercury concentration ratios among individual sampling sites correspond for the most part with those that have already been established for bream (Table 3), but at an overall much lower concentration level and with a smaller concentration spread (20 to 400 µg/kg ww within bream from the year 2000: factor 20; 5 to 50 µg/kg ww in the case of zebra mussels: factor 10). The lowest concentrations are found in samples from Belauer Lake, and somewhat higher concentrations (but often still below the EQS for biota) are found in the rivers Saar, Rhine and Danube. As in the case of bream, highest mercury concentrations are seen in samples from the Elbe. Results for mercury in zebra mussels from the rivers Saale and Mulde are not available in the GESB.

Mercury levels in zebra mussels do not correlate with those in bream at D3 (Jochenstein; comparatively lower concentration in mussels than in bream) and E5 (Blankenese; comparatively higher concentration in mussels than in bream), but better with those in SPM (Table 11).

Table 11: Comparison of mercury concentrations in SPM, bream and zebra mussels for the period 2000 to 2008/09 at different sites along the rivers Saar, Rhine, Danube and Elbe

Sites	**Hg concentration in SPM**	**Hg concentration in bream**	**Hg concentration in zebra mussels**
Saar – S1 (Güdingen)	0.2 – 0.3 mg/kg	≈ 100 µg/kg ww	5 – 15 µg/kg ww
Rhine – R1 (Weil)	≈ 0.2 mg/kg*	100 – 150 µg/kg ww	15 – 30 µg/kg ww
Rhine – R2 (Iffezheim)	≈ 0.4 mg/kg*	200 – 250 µg/kg ww	15 – 30 µg/kg ww
Rhine – R3 (Koblenz)	0.3 – 0.5 mg/kg	≈ 100 µg/kg ww	10 – 20 µg/kg ww
Rhine – R4 (Bimmen)	0.5 – 1.0 mg/kg	150 – 200 µg/kg ww	20 – 30 µg/kg ww
Danube – D3 (Jochenstein)	0.2 – 0.5 mg/kg	250 – 300 µg/kg ww	≈ 20 µg/kg ww
Elbe – E1 (Prossen)	1 – 2 mg/kg (Schmilka)	250 – 350 µg/kg ww	15 – 30 µg/kg ww
Elbe – E2 (Zehren)	1 – 2 mg/kg	300 – 400 µg/kg ww	25 – 40 µg/kg ww
Elbe – E4 (Cumlosen)	3 – 4 mg/kg (Schnackenburg)	200 – 350 µg/kg ww	20 – 40 µg/kg ww
Elbe – E5 (Blankenese)	1 – 2 mg/kg (Seemannshöft)	≈ 100 µg/kg ww	25 – 45 µg/kg ww

* Data source: International Commission for the Protection of the Rhine (ICPR) / German Rhine monitoring programme (DUR)

Unlike in bream and SPM from the Elbe, no significantly decreasing trends in mercury concentrations are seen in zebra mussels. An explanation of this might be that most data on zebra mussels were available not until the late 1990s (E5 in 1995, E4 and E3 in 1998, E1 in 1999 and E2 in 2000), whereas the strongest decline in concentrations in SPM and bream took place in the early 1990s.

6. Mercury concentrations in blue mussels

In addition to zebra mussels the GESB also samples blue mussels (*Mytilus edulis*), which are common in the coastal waters of the Baltic Sea and the North Sea. Blue mussels are primary consumers in the marine ecosystem that feed by filtering flowing water. They have good absorption and accumulation rates for numerous substances, and are relatively pollutant-resistant. The whole soft body of medium-sized blue mussels is analysed.

Samples are taken at two sampling sites in the North Sea and one in the Baltic Sea. GESB results expressed in µg/kg dry weight have been converted into wet weight (ww) by a factor of 0.15 assuming an average water content of the tissue of 85%. Mercury concentrations (10 to 15 µg/kg ww) in blue mussels from the Baltic Sea, comply with the EQS for biota, while those in mussels from the two sampling sites in the North Sea exceed the EQS with an average of more than 40 µg/kg ww clearly (Figure 9).

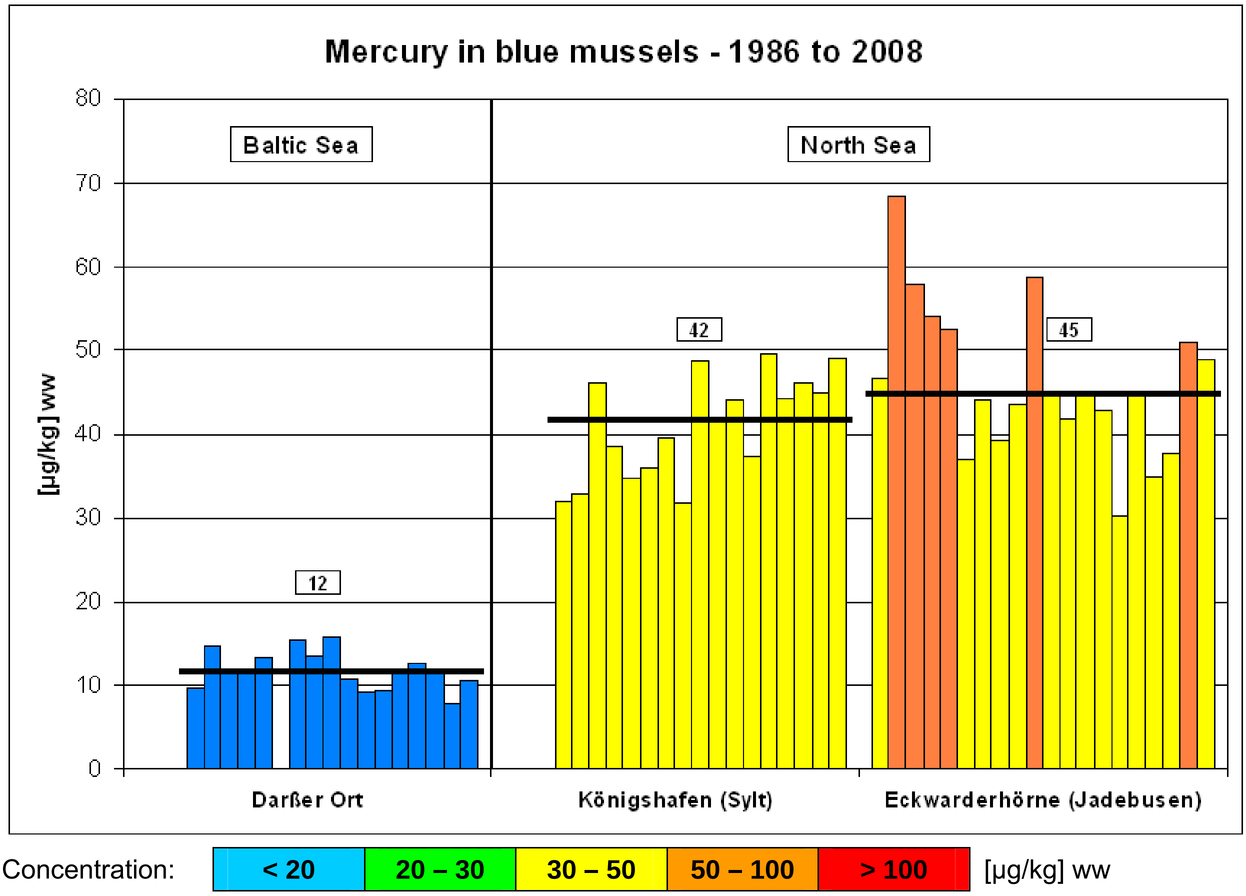


Figure 9: Mercury concentrations (µg/kg wet weight) in blue mussels from the Baltic See and the North Sea for the period 1986 to 2008. Horizontal bars and framed figures = median. Data source: German Environmental Specimen Bank (GESB)

Statistical examinations of the significance of differences in concentration and trends are shown in Tables 12 und 13.

Table 12: Statistical probability of differences in concentration between the individual data series "Mercury in blue mussels – 1986 to 2009“ (Figure 9), based on the non-parametric Mann-Whitney U test (two-sided) and a classic *t*-test (independent unpaired samples, two-sided); in each case upper row: U test, lower row: *t*-test

P [%]	**Darßer Ort**	**Königshafen**	**Eckwarderhörne**
Darßer Ort		**> 99.9** **> 99.9**	**> 99.9** **> 99.9**
Königshafen	**> 99.9** **> 99.9**		< 95 < 95
Eckwarderhörne	**> 99.9** **> 99.9**	< 95 < 95	

Classification:				
	not significant **< 95%**	**significant** **> 95%**	**very significant** **> 99%**	**highly significant** **> 99.9%**

Table 13: Statistical probability of trends in the individual data series "Mercury in blue mussels – 1986 to 2008" (Figure 9), based on the non-parametric Mann-Kendall trend test (one-sided)

Site	Statistical probability P for a trend
Darßer Ort	no trend
Königshafen	increasing: 99%
Eckwarderhörne	decreasing: 95%

Table 12 shows highly significant differences in mercury concentrations between blue mussels from the North Sea and the Baltic Sea, which are indicative of different pollution situations in these waters. At the Königshafen (Island of Sylt) sampling site there is, moreover, a significantly increasing trend in mercury concentrations in blue mussels.

7. Summary

- The ecologically reasoned EQS for biota of 20 µg/kg wet weight is exceeded in fish species in all German inland waters. The threshold limits of 1.0 and 0.5 mg/kg wet weight laid down for mercury in food fish for the protection of human health are, on the other hand, largely complied with. But also here, limits are exceeded in isolated cases.
- Mercury concentrations in bream from German rivers presently are between 100 and 400 µg/kg wet weight, and thus exceed the EQS for biota by a factor of 5 to 20.
- Differences in mercury concentrations in bream from varied sampling sites are statistically significant, and range from 20 to 50 µg/kg wet weight in Belauer Lake, the reference water body, to more than 300 µg/kg wet weight in the rivers Elbe and Saale.
- Maximum mercury concentrations of up to 800 µg/kg wet weight in bream from the Elbe and the Saale/Mulde in the 1990s have decreased to the present level of 300 to 400 µg/kg wet weight. The bream is thus suitable for monitoring changes in mercury pollution in inland waters.
- Mercury concentrations in SPM from the rivers Elbe and Saale/Mulde have also continually and significantly declined since the early 1990s.
- Mercury concentrations in zebra mussels from German rivers lie between 10 and 50 µg/kg wet weight, and exceed the EQS for biota by a factor of 2.5 at the most. Mercury concentrations in samples from Belauer Lake and the rivers Saar, Rhine and Danube often comply with or are slightly above the EQS.
- Mercury concentration ratios in zebra mussels among individual sampling sites are comparable to those for bream, but at a noticeably lower level and with a smaller concentration spread. The lowest mercury concentrations are found – as in the case of bream – in mussels from Belauer Lake, while the highest levels are seen in samples from the River Elbe. There is no decreasing trend in mercury concentration in zebra mussels from the Elbe. An explanation of this might be that most data on zebra mussels were available not until the late 1990s after the major decline in mercury levels had already been happened.

- Blue mussels from German coastal waters show mercury concentrations of between 10 and 60 µg/kg wet weight, which are thus on the same scale as those found in zebra mussels from inland waters. Mercury concentrations (10 to 15 µg/kg ww) in blue mussels from the Baltic Sea, comply with the EQS for biota, while those in mussels from the North Sea exceed the EQS with an average of more than 40 µg/kg ww clearly.

8. Conclusions and recommendations

Directive 2008/105/EC defines an EQS for mercury in biota. A transfer of this objective in equivalent quality standards for water or sediment is not possible by today's state of knowledge. The bream, as a wide distributed stenoecious fish species that restricts itself to a particular habitat, is appropiate for the control of this EQS. Fish represent the main food source of *inter alia* otters and ospreys, which ought to be protected against poisoning via the food chain ("secondary poisoning") [1].

The data shows, however, that the environmental quality standard for biota of 20 µg/kg wet weight is noticeably exceeded in bream in all German inland waters. That, in principle, the compliance with this EQS is problematic for fish, is also shown by published data from other countries, and in particular from remote areas [3, 4, 5, 6, 7]. Mercury concentrations in non-predatory fish from regions such as Canada, Alaska and Norway lie mostly between 20 and 100 µg/kg wet weight, but often also above this range and only in a few isolated cases below 20 µg/kg (concentrations are also dependent on the age and size of the fish under investigation). This concentration level, which has also been seen in Belauer Lake, the GESB reference water body, can therefore be regarded as a ubiquitous basic contamination in fish from waters that are largely unaffected by direct anthropogenic activity. These mercury levels are, besides geogenic sources, mainly attributable to the global atmospheric transport of mercury and subsequent deposition.

The analysis of mercury in zebra mussels is likewise appropriate for detecting varied concentrations of mercury in inland waters. The much lower concentrations of mercury in zebra mussels compared to bream might be traced back to the fact that the sampled mussels, aged 1 to 2 years, are considerably younger than the bream with their 8 to 12 years, and that accumulation occurs along the food chain.

When using mussels as study object, their sedentary way of life, is advantageous and facilitates sampling. However, the concentration distribution between lowly and highly contaminated sites shows a smaller concentration spread than in the case of bream. Moreover, in contrast to bream, no significant temporal trends for mercury could be established.

Acknowledgement

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Annex: Data

Mercury in bream in µg/kg dry weight (original values of the German Environmental Specimen Bank)

Sampling area	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belauer Lake	--	--	--	--	226	--	195	--	175	--	120	--	145	--	106	--	162
Saar – Güdingen	--	316	363	396	469	549	449	444	441	507	526	430	390	474	476	392	399
Saar – Rehlingen	--	398	512	517	466	459	575	633	546	603	569	610	462	536	584	510	524
Rhine – Weil	--	--	772	678	673	639	886	916	746	841	718	850	841	500	553	575	476
Rhine – Iffezheim	--	--	1206	1429	1022	935	913	1023	1042	1155	896	1142	1142	1098	688	1140	943
Rhine – Koblenz	--	--	878	805	546	367	493	478	441	426	381	393	408	553	472	500	815
Rhine – Bimmen	--	--	1391	1945	1415	1099	740	1223	847	927	561	823	942	863	648	851	988
Danube – Ulm	--	--	--	--	--	--	--	--	--	--	--	530	448	421	423	508	322
Danube – Kelheim	--	--	--	--	--	--	--	--	--	--	--	538	884	667	495	668	761
Danube – Jochenstein	--	--	--	--	--	--	--	--	--	--	--	1313	1336	1270	1053	1530	1407
Elbe – Prossen	2093	2618	2859	2456	1678	1784	2027	1658	1787	1585	1152	1592	1523	1532	824	1130	1213
Elbe – Zehren	2632	2934	3376	2505	2133	2259	2650	1852	2248	1973	1624	2033	2090	1852	1540	1488	1647
Elbe – Barby	1402	4196	3397	2856	2158	3022	2430	1843	1540	1050	1415	1447	1316	1220	1613	1292	1592
Elbe – Cumlosen	1299	2887	2758	2860	3286	2526	1398	1162	1041	1270	1532	1867	1956	1518	1492	1200	1095
Elbe – Blankenese	1650	1628	1464	1629	1133	1067	1159	1258	901	524	465	572	418	489	534	578	556
Saale – Wettin	--	--	1455	969	943	1035	1248	1655	1422	1638	1546	1622	1962	1698	1830	1717	1450
Mulde – Dessau	--	--	4127	3439	3032	2719	2521	1445	1487	1520	916	1122	1115	1363	1255	1007	1053

Mercury in bream in µg/kg wet weight (converted with a factor of 0.2)

Sampling area	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belauer Lake	--	--	--	--	45	--	39	--	35	--	24	--	29	--	21	--	32
Saar – Güdingen	--	63	73	79	94	110	90	89	88	101	105	86	78	95	95	78	80
Saar – Rehlingen	--	80	102	103	93	92	115	127	109	121	114	122	92	107	117	102	105
Rhine – Weil	--	--	154	136	135	128	177	183	149	168	144	170	168	100	111	115	95
Rhine – Iffezheim	--	--	241	286	204	187	183	205	208	231	179	228	228	220	138	228	189
Rhine – Koblenz	--	--	176	161	109	73	99	96	88	85	76	79	82	111	94	100	163
Rhine – Bimmen	--	--	278	389	283	220	148	245	169	185	112	165	188	173	130	170	198
Danube – Ulm	--	--	--	--	--	--	--	--	--	--	--	106	90	84	85	102	64
Danube – Kelheim	--	--	--	--	--	--	--	--	--	--	--	108	177	133	99	134	152
Danube – Jochenstein	--	--	--	--	--	--	--	--	--	--	--	263	267	254	211	306	281
Elbe – Prossen	419	524	572	491	336	357	405	332	357	317	230	318	305	306	165	226	243
Elbe – Zehren	526	587	675	501	427	452	530	370	450	395	325	407	418	370	308	298	329
Elbe – Barby	280	839	679	571	432	604	486	369	308	210	283	289	263	244	323	258	318
Elbe – Cumlosen	260	577	552	572	657	505	280	232	208	254	306	373	391	304	298	240	219
Elbe – Blankenese	330	326	293	326	227	213	232	252	180	105	93	114	84	98	107	116	111
Saale – Wettin	--	--	291	194	189	207	250	331	284	328	309	324	392	340	366	343	290
Mulde – Dessau	--	--	825	688	606	544	504	289	297	304	183	224	223	273	251	201	211

Mercury in zebra mussels in µg/kg dry weight (original values of the German Environmental Specimen Bank)

Sampling area	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Belauer Lake	--	--	--	77	--	68	--	42	--	33	--	50	--	43	--
Saar – Güdingen	80	96	60	81	--	68	99	63	57	40	65	47	60	78	91
Saar – Rehlingen	133	68	93	196	78	66	91	44	38	35	44	42	49	65	48
Rhine – Weil	--	146	62	108	--	173	--	--	--	--	167	--	187	--	--
Rhine – Iffezheim	--	164	94	134	--	--	--	--	--	--	204	--	--	--	--
Rhine – Koblenz	--	156	71	103	--	--	--	--	--	--	147	88	95	55	84
Rhine – Bimmen	--	130	67	172	--	155	--	122	--	--	122	136	--	197	173
Elbe – Prossen	--	--	--	--	--	182	178	199	216	94	80	121	107	106	118
Elbe – Zehren	--	--	--	--	--	--	170	272	189	253	213	219	202	151	246
Elbe – Barby	--	--	--	--	251	231	234	265	258	336	211	145	114	151	138
Elbe – Cumlosen	--	--	--	--	191	147	176	146	315	--	--	115	125	180	121
Elbe – Blankenese	--	242	329	244	260	305	306	164	--	211	216	--	245	273	222
Danube – Ulm	--	--	--	--	--	--	--	--	--	--	--	--	--	--	58
Danube – Kelheim	--	--	--	--	--	--	--	--	--	--	--	--	--	--	119
Danube – Jochenstein	--	--	--	--	--	--	--	--	--	--	--	--	--	--	120

Mercury in zebra mussels in µg/kg wet weight (converted with the factor of 0.15)

Sampling area	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Belauer Lake	--	--	--	11	--	10	--	6	--	5	--	8	--	6	--
Saar – Güdingen	12	14	9	12	--	10	15	9	8	6	10	7	9	12	14
Saar – Rehlingen	20	10	14	29	12	10	14	7	6	5	7	6	7	10	7
Rhine – Weil	--	22	9	16	--	26	--	--	--	--	25	--	28	--	--
Rhine – Iffezheim	--	25	14	20	--	--	--	--	--	--	31	--	--	--	--
Rhine – Koblenz	--	23	11	15	--	--	--	--	--	--	22	13	14	8	13
Rhine – Bimmen	--	19	10	26	--	23	--	18	--	--	18	20	--	30	26
Elbe – Prossen	--	--	--	--	--	27	27	30	32	14	12	18	16	16	18
Elbe – Zehren	--	--	--	--	--	--	26	41	28	38	32	33	30	23	37
Elbe – Barby	--	--	--	--	38	35	35	40	39	50	32	22	17	23	21
Elbe – Cumlosen	--	--	--	--	29	22	26	22	47	--	--	17	19	27	18
Elbe – Blankenese	--	36	49	37	39	46	46	25	--	32	32	--	37	41	33
Danube – Ulm	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9
Danube – Kelheim	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18
Danube – Jochenstein	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18

Mercury in suspended particulate matter (SPM) in mg/kg dry weight

Sampling area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Saar – Güdingen	--	--	--	--	0.27	0.26	0.30	0.25	0.25	0.24	0.20	0.24	0.26	0.20	0.22	0.23	0.20	0.21	0.14
Rhine – Koblenz	0.83	0.78	0.37	0.46	0.26	0.21	0.25	0.25	0.37	0.39	0.38	0.38	0.34	0.41	0.36	0.33	0.36	0.34	0.30
Rhine – Kleve-Bimmen	0.69	1.53	0.81	0.75	0.39	0.49	0.69	0.62	0.68	0.45	0.50	0.50	0.41	0.86	0.52	0.59	0.48	0.43	0.46
Danube – Kelheim	--	--	--	--	11.8	0.53	2.3	0.20	0.60	0.65	0.10	0.97	0.35	--	--	--	--	--	--
Danube – Jochenstein	0.37	0.36	0.52	0.21	0.30	0.55	0.15	0.10	0.05	0.10	0.05	0.39	0.40	0.34	0.30	0.22	0.28	0.27	0.21
Elbe – Schmilka	--	--	--	--	--	4.9	8.4	3.3	2.7	2.7	2.2	2.0	1.7	1.6	1.3	1.7	0.8	1.0	1.5
Elbe – Zehren	--	--	--	--	--	--	--	--	--	--	--	1.7	1.0	0.91	0.82	0.99	0.92	0.65	0.93
Elbe – Schnackenburg	20.2	27.8	12.3	10.1	7.3	5.8	4.4	5.2	4.1	3.6	3.2	3.5	3.4	2.5	2.8	3.5	--	--	--
Elbe – Seemannshöft	--	--	8.1	4.8	5.5	4.8	3.1	2.0	1.8	1.8	1.7	1.3	1.8	1.7	1.4	1.2	1.1	1.0	1.1
Saale – Groß Rosenburg	--	--	--	--	7.8	7.7	4.3	6.6	5.4	7.2	6.0	5.3	4.3	6.6	5.6	4.6	3.2	2.2	3.0
Mulde – Dessau	--	--	--	--	--	7.0	7.2	5.0	3.9	3.2	3.2	2.3	2.9	2.7	2.4	1.8	1.6	1.8	1.7

Mercury in blue mussels in µg/kg dry weight (original values of the German Environmental Specimen Bank)

Sampling area	1986	1988	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Darßer Ort	--	--	--	65	98	79	82	88	--	102	90	105	72	61	62	81	84	77	52	71
Königshafen (Sylt)	--	--	--	212	219	308	258	232	240	265	212	325	278	294	249	332	295	308	300	328
Eckwarderhörne (Jadebusen)	310	457	386	361	351	247	293	261	289	392	298	279	302	287	202	303	233	251	339	326

Mercury in blue mussels in µg/kg wet weight (converted with the factor of 0.15)

Sampling area	1986	1988	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Darßer Ort	--	--	--	10	15	12	12	13	--	15	13	16	11	9	9	12	13	12	8	11
Königshafen (Sylt)	--	--	--	32	33	46	39	35	36	40	32	49	42	44	37	50	44	46	45	49
Eckwarderhörne (Jadebusen)	47	69	58	54	53	37	44	39	43	59	45	42	45	43	30	45	35	38	51	49