Report on Contamination of Fish with Pollutants in the Catchment Area of the Rhine

Ongoing and Completed Studies in the Rhine States

(2000 – 2010)
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Summary

The present report brings together data from the Rhine States, for the period 2000 to 2010, on the contamination with various pollutants of fish in that river and its tributaries. In the case of eel, a virtually area-wide violation of the total highest value permissible under foodstuffs legislation was determined in the Rhine and many of its tributaries for dioxins, furans, and dioxin-like PCBs (WHO TEQ, 12 g/g fresh weight (FW)). Eel samples from Lake Constance and a former branch of the Rhine are an exception, consistently displaying no excess. Overall, significant fluctuations in the content of dioxins and PCBs were found in all the species of fish studied. The values range from less than 1 g/g FW in the case of carp species to more than 70 g/g FW in eel. The contamination is not species-specific but depends on the pollution situation of the water body concerned at the sampling site and on the age and fat content of the individual fish.

In the course of the ICPR’s suspended matter measurement programme (1991 to 2007), the sole dioxin-like PCB congener measured was PCB 118. The results indicate a decrease in contamination with PCB 118.

The limits for indicator PCBs under German and Dutch law are sporadically exceeded in the Rhine itself and in the Moselle and Main, namely in older, fat-rich eel and bream, but not in other fish species. In eel from the Delta Rhine (sedimentation area in the Waal and in the Ketelmeer), contamination of eel with indicator PCBs (6 congeners, 1978 to 2009) has decreased significantly since the 1980s, from values in excess of 3 mg/kg FW to values below 0.5 mg/kg FW. A similar trend is apparent in the Moselle and, to a lesser extent, in the Saar.

In the High, Upper, and Middle Rhine, 2008 was the first time that no violation of the maximum levels permissible under the (German) ordinance on maximum quantities of residue [Rückstandshöchstmengenverordnung, RHmV] was determined for hexachlorobenzene (HCB) (0.05 mg/kg FW or 0.5 mg/kg fat). These levels are still sporadically exceeded in eel in the Main area and in the Middle Rhine. In the Delta Rhine, a major decrease since the 1970s in HCB contamination of yellow eel was apparent, from more than 0.1 mg/kg FW to values of about 0.01 mg/kg FW. In Lake IJsselmeer, the environmental quality standard (EQS) for biota according to Directive 2008/105/EC was achieved, namely 0.01 mg/kg FW.

Studies of perfluorinated tensides (PFTs) found clearly raised quantities in particular in Rhine fish (Delta Rhine, Lower Rhine, Upper Rhine, High Rhine) of perfluorooctanesulfonic acids (PFOS, 3 µg/kg to more than 70 µg/kg FW; EQS proposed value: 9.1 µg/kg FW). The trend analysis in the Netherlands showed an increase since the 1970s until the mid-1990s, followed by a decrease to values of 7 to 58 µg/kg FW. For other PFTs, the values in the whole of the Rhine area were generally below the detection limit.

The maximum levels of mercury permissible under foodstuffs legislation (according to EU Regulation 1881/2006: 1 mg/kg FW for eel and 0.5 mg/kg FW for other fish species) were only sporadically exceeded during the reporting period; values were generally between 0.7 and 0.35 mg/kg. However, the decrease in the concentration of mercury in Rhine fish that was observed in the 1980s and 1990s has not continued. The EQS for biota of 0.02 mg/kg FW for mercury is exceeded comprehensively and systematically in all parts of the catchment area of the Rhine.

Despite the extensive data available, the studies concerned revealed patterns of distribution at no more than regional level. A standardised procedure for sampling through to analysis could make possible assessment of the contamination of fish at the level of the catchment area of the Rhine. Well-founded conclusions with relevance for the aquatic ecosystem would require data derived from scientific approaches to investigation.
1. Introduction

1.1 Objective and task

In the past few decades, extensive discharges of pollutants have led to large quantities of contaminated sediments being deposited in the Rhine and its tributaries, particularly in the sections where the flow is regulated. Despite production and use of most of these substances having been terminated, with no more direct discharges being known, sediment quality continues to be negatively affected by the presence of these substances at sites contaminated in the past, and they can be expected to continue to be present in the water bodies concerned for a long time. Old sediments can be whirled up during flooding or dredging, for example. Fish reflect the pollution of sediments. Under the Rhine Convention, ecosystem aspects are of interest to the ICPR, in particular the accumulation of pollutants in the food chain and the assessment of fish health and the ecosystem.

It was against this background that the ICPR’s Strategy Group (SG) requested the Ecology Working Group (WG B) – or in fact its Fish Experts Group (EG FISH) – to first of all assemble the data available in the Rhine States for the years 2000 to 2010 so as to survey the contamination of Rhine fish (and also fish from the Rhine tributaries) with “dioxin-like PCBs” and other pollutants. The assembled data would be analysed and the trend in recent years would be described.

The aim of the present report is to provide an overview of the large-area distribution of the contamination of Rhine fish with dioxins, furans and dioxin-like PCBs, as well as indicator PCBs in the Rhine catchment area and also – insofar as this is known – to provide an overview of the trend in that contamination. Where sufficient data is available, statements would also be made regarding HCB, HCBD, PFTs and other organic pollutants as well as heavy metals, especially mercury. The trends in contamination with these substances are ecologically significant and EC Directive 2008/105/EC requires that they be monitored (for example heavy metals, HCB, HCBD).\(^1\)

Due to the great heterogeneity of the available data, most of the data is not comparable; a textual explanation of the situation in the individual Rhine States (or the relevant German federal states) is therefore given. Reliable values for the sum of dioxins, furans and dioxin-like PCBs (WHO TEQ, see 2.2) have been provided in Appendix 5.

Between 1995 and 2000, the Member States of the ICPR also carried out coordinated programmes for measuring the contamination of fish in the Rhine, after the available Rhine fish data had been compiled and evaluated in 1990.\(^2\) The results are summarised in Section 1.3.

Based on the combined results presented in this report, consideration will be given within the ICPR to whether there should be studies of contamination of Rhine fish in the framework of the next international Rhine measurement programme (2012/2013).

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2 See ICPR Report No. 124, [www.iksr.org – Documents/Archive - Technical reports](http://www.iksr.org)
1.2 Origin of the pollutants studied and their effect on the environment

Dioxins, furans and polychlorinated biphenyls

Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDF) are formed as by-products of combustion processes and industrial processes in the presence of chlorine. In the past, the main emission sources were plants involving chlorine chemistry, domestic waste incineration (a source that has now been greatly reduced), power generation, and metal smelting. Dioxins and furans are persistent in the environment; they are not very water soluble and accumulate in sediments and organic matter as well as in organisms. They are taken up mainly via food, especially via more heavily polluted benthic organisms, but also directly via water, the gills, and the skin.

Polychlorinated biphenyls (PCBs) are industrially produced substances that were used, for example, in transformers, hydraulic systems, refrigerators, as softeners in plastics and as flame retardants in paints and varnishes. Production and use of PCBs have long been prohibited (NL: since 1985, CH: since 1986, FR: since 1987, DE: since 1989, whole EU: since 2004), but they are still sporadically released from PCB-containing materials (for example building facades) and sites contaminated in the past, and can also be formed during thermal processes. Some PCBs (dioxin-like PCBs) can have similar toxic effects to dioxins (see Table 1).

PCBs are in generally poorly soluble in water. The intake of dioxins, furans, PCBs and other lipophilic pollutants in fish occurs both via their diet and through their gills and skin (bioconcentration). The significance of these two entry pathways, which together account for bio-accumulation (accumulation in the organism), differs depending on the species, age and life stage. If the pollutants accumulate further up in the food web, one refers to “biomagnification” (see Figure 1). This increases the risk of toxic effects.

Another important factor is the species-specific metabolism of organic pollutants (biotransformation): non-excretable substances (mostly lipophilic) can be converted with varying degrees of intensity by means of chemical processes into excretable substances. Biotransformation and/or excretion mean, however, that higher trophic levels sometimes have a comparable or even lower quantity of residue. In the case of biomagnification, the decisive mechanism is either bioconcentration or biotransformation is less intense and the pollutants are not excreted but accumulate in fat. In the case of absorption via body surfaces (bioconcentration), there is first a partition equilibrium between water and blood, and then between blood and fat in the organs. Intake of pollutants through food and excretion are initially in equilibrium; however, if the body fat content increases and the habitat is polluted, the quantity of residue in the organism also increases. Nevertheless, final links in the food chain that do not live purely aquatically – including not only fish-eating birds but also humans – do not have the corresponding excretion routes (because of their pulmonary respiration) – meaning that intake through food and consequently accumulation in the food web is decisive here.

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3 See Parey 1986: Pike and roach from the Upper Rhine – two fish species that are in a predator-prey relationship – displayed a similar level of contamination and a similar fat content.
Figure 1: Pollutants in the aquatic food web. Simplified food web of the eel. Red circles symbolise contaminant exposure via sediments, Yellow circles symbolise exposure via water. The number of circles indicates the relationship between intake via sediments and intake via water. That relationship is variable and depends on the particular contaminant. The more circles or the larger an individual circle, the higher the concentration of pollutant. At the higher levels of the food web – particularly in top predators (which include not only predatory fish and birds but also humans) – the pollutants accumulate and biomagnification occurs. (Source: Van den Heuvel-Greve et al. 2009)

The habits of a fish also play a role in this connection. Fish that spend their time primarily at the bottom of the water body, for example, are in close contact with recent sediments and take up pollutants that may be stored there – not only if their diet includes benthic organisms – more readily than fish that spend most of their time in the main part of the water body.

Fat-rich fish therefore basically have a greater potential for accumulating PCBs. A higher fat content is in turn typical of some species such as eel and fish of the Salmonidae family (salmon and trout-like species such as whitefish and char, see Figure 2, Appendix 3). Because hardly any breakdown of dioxins or PCBs occurs in cold-blooded animals, increasing age means that residues accumulate in their fatty tissue. Older and
larger individuals, which generally have a higher fat content, therefore tend to be more highly contaminated with PCBs.

**Figure 2**: Dependence of TEQ (PCDD/F + DL-PCBs) value on fat content of fish. All samples from Lake Geneva. Source: BAFU (Schmid et al. 2010)

As long as pollutants are stored in the fat deposits, their toxic effects are relatively limited. If the fat reserves are reduced, however, the PCBs are remobilized and toxic PCB metabolites (breakdown products) are created. Pollutant concentrations in the blood plasma increase, resulting in physiological stress. PCBs are stored at increased levels in other tissues and organs, where they can also have adverse effects. The toxic effects of PCBs are based, amongst other things, on interactions with receptors, proteins, or DNA.

In laboratory experiments, deformities and increased mortality in fish embryos due to exposure to organic chlorine compounds such as PCDD/F and PCBs were observed in pike, carp, lake trout, rainbow trout, and eel.\(^4\) An incubation and rearing experiment with pike from the Upper Rhine revealed a high correlation between contamination of spawning fish with organochlorines (primarily PCBs, but also hexachlorobenzene) and the fertilization rate, the percentage of normally developed embryos at hatching time and the hatch rate overall. No such correlation could be demonstrated in the case of roach.\(^5\) There is no evidence for such effects on fish in the field because such experiments are very difficult or practically impossible.

In the case of the eel – whose high fat content means that it is generally the most heavily polluted species of fish in the Rhine catchment area – contamination with DL-
PCBs and other anthropogenic pollutants may be one of the reasons for declining stocks.\(^6\) In particular, about half the fish’s fat reserves are consumed during the spawning migration and also as preparation for spawning. This leads to the release of stored persistent pollutants such as PCBs.

**Hexachlorobenzene (HCB)**

HCB was used as a plant protection product (fungicide), in the treatment of seeds, in wood preservatives, and as an additive for PVC, insulation materials, and adhesives. It is also created during the production, processing, and incineration of other substances containing chlorine, for example as a by-product of the production of plastics and solvents. Since the 1980s, HCB has no longer been permitted as a plant protection product in the Rhine States. It is now only produced and utilised industrially on a limited scale, and it enters the environment primarily from sites contaminated in the past. HCB displays high toxicity particularly in small crustaceans and fish.

**Perfluorinated tensides (PFTs)**

PFTs (PFOA = perfluorooctanoic acid, perfluorooctane sulphonate = PFOS) are produced industrially and are contained in a large number of products. Waste water from electroplating plants, waste water containing solvents, and waste water from textile or paper finishing or waste disposal operations/landfills can be particularly polluted. In 2006, a high level of PFT pollution was found in the Ruhr and its tributary the Möhne (North Rhine-Westphalia); this consisted primarily of PFOA and could be traced to the illegal addition of industrial waste to fertilisers or soil additives. Since 2006, PFTs have been detected as part of the official measurement programme. Since 2008, PFOS can only be utilised within the EU in a few exceptional cases.

PFTs are toxic to humans and animals, accumulate in the blood and organ tissues, and are suspected of causing cancer. The lowest level of an average acute lethal concentration (LC50) of PFOS in water was found in shrimp (*Americamysis bahia*) at 3.6 mg/l. As a chronic effect, negative effects on the hatching of midge larvae (*Chironomus tentans*) have been documented from a concentration of 21.7 µg/l (NOEC).\(^7\)

No maximum limits or guideline limits for perfluorinated tensides (PFTs) in fish have yet been specified. In Germany only a guidance value of 30 µg/kg FW has been derived.\(^8\)

Concentrations of PFOS in water are in the nanogram range, and in the Rhine usually below the detection limit. Species-specific bio-accumulation factors for fish can be calculated as a quotient from the concentration of PFOS in fish muscle tissue (µg/kg DM) and water (µg/kg water). In the Lower Rhine (using half the detection limit for the PFOS concentration in water) and its tributaries these are at a factor of 1000 to 2000 and are highest in perch (2284), eel (1799) and bream (1731) and lowest in chub (539) (see Appendix 6).\(^9\)

\(^6\) See Belpaire et al. 2011  
\(^8\) See BfR 2008  
\(^9\) LAWA 2010
Intake of PFOS from consumption of fish can account for more than 90% of total exposure from food, although only 1.5% to 2.5 of the tolerable lifelong intake is used up.\textsuperscript{10}

**Mercury (Hg)**
Mercury is a heavy metal that occurs in nature, for example in rocks of volcanic origin. Major anthropogenic sources include the burning of coal, the chlorine/alkali industry, and use in products including dental fillings (amalgam), measuring and control equipment, and batteries. Most of the mercury in water bodies is bound inorganically in sediments. Microorganisms in the bed of the water body can convert mercury into methylmercury. This is more easily absorbed by organisms and accumulates in the food web.

\textsuperscript{10} See BfR 2008; calculation based on current measurements of PFT levels in foods and the average intakes of different food groups determined by the Robert Koch Institute in 1998 as part of a Germany-wide nutrition survey.
### Table 1: Ecotoxicological characteristics of PCBs, dioxins, furans, HCB, PFOS, and mercury

<table>
<thead>
<tr>
<th>Substance group</th>
<th>Dioxins, furans, DL-PCBs</th>
<th>Indicator PCBs</th>
<th>HCB</th>
<th>PFOS</th>
<th>Methylmercury</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>complex, binding both organic and inorganic</td>
</tr>
<tr>
<td><strong>Breakdown</strong></td>
<td>very slow</td>
<td>no</td>
<td></td>
<td></td>
<td>not at all</td>
</tr>
<tr>
<td><strong>Intake in organisms</strong></td>
<td>via food, suspended matter, water</td>
<td>via food and water</td>
<td>via food, sediments, water</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>in fatty tissue, in the liver</td>
<td>in fatty tissue, in the liver, kidneys and lymph glands</td>
<td>in muscle and fatty tissue, in the liver</td>
<td>in fatty tissue, the liver, the skin</td>
<td></td>
</tr>
<tr>
<td><strong>Bioaccumulation</strong></td>
<td>throughout the food web</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toxicity in water bodies</strong></td>
<td>Negative effects on food intake, weight, reproduction, development, immune system, behaviour</td>
<td>Damage to nervous system (including narcotic effects), negative effects on the skin, liver, kidneys, digestive system</td>
<td>Toxic to fish and small organisms in water bodies</td>
<td>Acutely poisonous (for example for shrimps), chronic effects, for example on the hatching of midge larvae</td>
<td></td>
</tr>
<tr>
<td><strong>Toxicity in humans</strong></td>
<td>Skin rash (chloracne), damage to the liver, reproductive organs and immune system, developmental disorders, carcinogenic. Some PCBs stimulate the growth of tumours.</td>
<td>Damage to nervous system, liver, lungs, reproductive organs; carcinogenic</td>
<td>Lethal at high doses</td>
<td>Suspected of being carcinogenic</td>
<td>Negative effects on development of nerves, heart, blood vessels, immune system, and reproductive organs; possibly carcinogenic</td>
</tr>
</tbody>
</table>
1.3 Pollution of fish in the Rhine main stream in 2000

(Excerpts from ICPR report No. 124)

In 2000, the ICPR programme for measuring contamination of fish in the Rhine catchment area showed that pollution by polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB) and mercury (sporadically) must be viewed as problematic from the point of view of foodstuffs legislation, whereas contamination by the other pollutants considered (pesticides, other semi-volatile hydrocarbons, tri- and tetrachlorobenzenes, nitro-musk compounds, lead, cadmium, bromocyclen, triphenyl- and tributyltin) were of comparatively minor importance. This finding was in line with the outcome of the measurement programme carried out by the ICPR in 1995.

Concentrations of **lower chlorinated polychlorinated biphenyls (PCBs)** showed a spatial focus of contamination in the Lower Rhine and Delta Rhine. No differences were observed in this spatial distribution between the situation in 2000 and that in 1995; in the Lower Rhine, however, a highly significant decrease in pollution was observed for that period. Comparatively high levels of higher chlorinated PCBs were observed downstream of Mannheim (Rhine km 432). No significant decrease over time was apparent as far as the Middle Rhine. In the case of the Lower Rhine and all sections of the Rhine taken together, there was a significant decrease in contamination. The maximum levels of higher chlorinated PCBs permissible under foodstuffs legislation were exceeded at virtually all the measurement locations on the Middle and Lower Rhine. The applicable Dutch maxima were not found to be exceeded in eel from the Delta Rhine; in the case of roach, they were only exceeded sporadically.\(^\text{11}\) The overall percentage of legally relevant individual samples for the major congeners **PCB 138** and **PCB 153** was 21% or 28%, i.e. the same as in 1995.

Over the course of the Rhine, contamination of eel samples with **hexachlorobenzene** (HCB) showed a steep rise commencing in the lower Upper Rhine and continuing into the northern Upper Rhine. The highest HCB levels were found in the Upper and Middle Rhine as far as Koblenz, with the majority of the eel examined exceeding the maximum permissible under foodstuffs legislation. Levels then fell clearly in the further course of the river. The roach examined were within the norm from the point of view of foodstuffs legislation. Pollution had decreased significantly compared to 1995 in the vicinity of the former specific discharger on the Upper Rhine. At the start of the southern Upper Rhine (Grißheim, Rhine km 210), the concentrations measured remained the same, namely at a very high level. However, for the rest of the Rhine as far as Bad Honnef (Rhine km 642), a significant increase in pollution was observed at all the measurement locations. In the northern Upper Rhine, the average level of pollution was in fact higher than that in 1990.

Contamination of eel with **mercury** showed an increase beginning in the Upper Rhine and continuing in the southern Upper Rhine. The average level of contamination decreased slightly further downstream. Compared to 1995 and also 1990, a clear increase was observed in the level of mercury in eel in the Upper Rhine. By contrast, contamination of eel in the Middle Rhine was significantly lower than the value observed in 1995. Throughout the course of the Rhine, the maximum levels for mercury that applied back then\(^\text{12}\) were not exceeded. The German Environmental Specimen Bank’s [Umweltprobenbank] data for bream – which were used for comparison – lead to similar interpretations for the main pollutants, in particular for hexachlorobenzene and mercury.

\(^{11}\) The maximum levels for PCB-153 in mg/kg FW at that time were: in the Netherlands, for eel 0.5 and for other fish 0.1; in Germany, 0.2 for all species of fish (in terms of fat in fish with a fat content of > 10%).

\(^{12}\) Maximum levels for mercury at the time in mg/kg FW: Switzerland, 0.5; Germany 0.5 or 1.0 for eel, pike and perch; Netherlands 1.0.
2. Underlying data

2.1 Participating organisations in Rhine catchment area

The following organisations made contributions to this report:

**Switzerland:** Bundesamt für Umwelt (BAFU), Bern – [www.bafu.ch](http://www.bafu.ch)

**France:** Office National de l’Eau et des Milieux Aquatiques (ONEMA), Vincennes (Île-de-France) – [www.onema.fr](http://www.onema.fr)
Agence Nationale de Sécurité Sanitaire (ANSES, previously AFSSA), Maisons-Alfort (Île-de-France) – [www.anses.fr](http://www.anses.fr)

**Germany:**

- **Baden-Württemberg:** Chemisches und Veterinäruntersuchungsamt Freiburg (CVUA) – [www.ua-bw.de](http://www.ua-bw.de)
- **Bavaria:** Bayerisches Landesamt für Umwelt (LfU), Dienststelle Wielenbach
  Landesamt für Gesundheit und Lebensmittelsicherheit (LGL), Oberschleißheim
- **Saarland:** Landesamt für Umwelt- und Arbeitsschutz (LUA), Saarbrücken – [http://www.saarland.de/landesamt_umwelt_arbeitsschutz.htm](http://www.saarland.de/landesamt_umwelt_arbeitsschutz.htm)
- **Rhineland-Palatinate:** Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht (LUWG), Mainz – [www.luwg.rlp.de](http://www.luwg.rlp.de)
- **Hesse:** Landesbetrieb Hessisches Landeslabor (LHL), Wiesbaden – [www.lhl.hessen.de](http://www.lhl.hessen.de)

**North Rhine-Westphalia:** Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV), Recklinghausen – [www.lanuv.nrw.de](http://www.lanuv.nrw.de)

**Federal:** Umweltbundesamt, Dessau – [www.umweltbundesamt.de](http://www.umweltbundesamt.de)

**Moselle-Saar area:** International Commission for the Protection of the Moselle and Saar (ICPMS), Trier – [www.iksms-cipms.org](http://www.iksms-cipms.org)

**Luxembourg:** Ministère de l’Intérieur/Administration de la Gestion de l’Eau – [www.waasser.lu](http://www.waasser.lu)

**Netherlands:** Rijkswaterstaat/Waterdienst (RWS), Lelystad – [www.rijkswaterstaat.nl](http://www.rijkswaterstaat.nl)
Institute for Marine Resources & Ecosystem Studies (IMARES), Wageningen – [http://www.imares.wur.nl](http://www.imares.wur.nl)
Instituut voor Voedselveiligheid (RIKILT) – [http://www.rikilt.wur.nl](http://www.rikilt.wur.nl)

The technical contacts are listed in Appendix 1.

Some reports and/or data are publicly available on the organisations’ websites (for further details, see Section 3).
2.2 Pollutants, parameters, and maximum levels studied

Appendix 2 shows which pollutants were studied in fish in which Rhine States. In addition to indicator PCBs, dioxins/furans and DL-PCBs, most states also recorded HCB and mercury in fish. Levels of other persistent organic pollutants were also measured.

Table 2 shows the maximum levels for eel and other fish that are relevant to evaluation. The maximum levels permissible under foodstuffs legislation are taken from
- EU Contaminants Regulation No 1881/2006, which also applies by analogy in Switzerland;
- Commission Recommendation 2006/88/EC;
- the proposal by the European Commission’s Directorate-General for Health and Consumer Protection (DG SANCO);
- national regulations.

The environmental quality standards (EQS) for biota pursuant to the WFD “Priority Substances” Daughter Directive (Directive No. 2008/105/EC, Article 3(2) are also included. The lipophilic nature of the substances concerned makes them difficult to measure in water. Measurements in biota are simpler and also give a better time-integrated picture of the water quality than random measurements in water. The standards in Table 2 for biota (fish, shellfish) in the European water bodies subject to the Water Framework Directive listed in Table 2 were therefore drawn up in 2007. Application of the “biota standards” is left to the Member States.

The toxicity of the sum of dioxins, furans and dioxin-like PCBs relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) is given in toxicity equivalent quantities (WHO TEQ ng/kg SC). This sum parameter was calculated in the most recent studies by all the Rhine States and is therefore used in the present report as a comparison parameter. The results for the WHO TEQ are not comparable because measurement of DL-PCBs was not foreseen in the ICPR measurement programme in 2000.

Of the non-dioxin-like PCBs, the congener PCBs 28, 52, 101, 138, 153, and 180 were combined as indicator PCBs. Of this group, it is normally congener PCB 153 that has the highest level, and it is therefore often utilised as a guide congener. At present, the assessment of the indicator PCBs according to foodstuffs legislation takes place in Germany according to the individual congeners; in future, however, it will be harmonised for all EU Member States on the basis of the sum of the indicator PCBs. DG SANCO is currently considering extension of the Regulation with maximum levels for the sum of the six indicator PCBs. A draft biota standard is also being derived, according to a harmonized European method, for the sum of seven indicator PCBs congeners.

The TEQ levels of polycyclic aromatic hydrocarbons (PAHs) are generally very low; they have not therefore been considered below.

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13 Fraunhofer Institute fact sheets
14 2008/105/EC, footnote (9) on page 10
15 Sum TEQ according to SANCO/13329/2010 + SANCO/13331/2010 revision 2
16 Duinhoven et al. 2007
Table 2: Maximum levels, action levels, environmental quality standards (EQS), EQS proposals and guidance values for dioxins, furans and DL-PCBs, indicator PCBs, HCB, hexachlorobutadiene, PFOS and mercury in eel and other fish according to EU and national legislation

<table>
<thead>
<tr>
<th>Substance</th>
<th>Type of fish</th>
<th>Legal basis</th>
<th>Maximum level(^\text{17})</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dioxins, furans, DL-PCBs</td>
<td>all</td>
<td>EU Regulation</td>
<td>4.0</td>
<td>ng WHO-PCDD/F-TEQ/kg FW (^\text{18})</td>
</tr>
<tr>
<td></td>
<td>all</td>
<td>Com. Rec.</td>
<td>3.0</td>
<td>ng WHO-PCB-TEQ/kg FW</td>
</tr>
<tr>
<td>DL-PCBs</td>
<td>eel</td>
<td>Com. Rec.</td>
<td>6.0</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td>other fish</td>
<td>Com. Rec.</td>
<td>3.0</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>Σ dioxins/furans/DL-PCBs</td>
<td>eel</td>
<td>EU Regulation</td>
<td>12.0</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td>other fish</td>
<td>EU Regulation</td>
<td>8.0</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>PCB 28, 52, 101, 180</td>
<td>freshwater fish</td>
<td>Kont.-VO D</td>
<td>0.2</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>PCB 138, 153</td>
<td></td>
<td></td>
<td>0.3</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td>diadromous fish caught in freshwater</td>
<td>DG SANCO proposal</td>
<td>0.075</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td>other freshwater fish in the wild</td>
<td></td>
<td>0.125</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>6 indicator PCBs (ICES 6):</td>
<td>all (for the present)</td>
<td>Draft biota standard</td>
<td>0.335</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>PCB 28, PCB 52, PCB 101, PCB 138,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB 153, PCB 180</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>all</td>
<td>Biota standard</td>
<td>0.01</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RHmV</td>
<td>0.5</td>
<td>mg/kg fat</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EQS proposal</td>
<td>9.1</td>
<td>µg/kg FW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BfR orientation value</td>
<td>30</td>
<td>µg/kg FW</td>
</tr>
<tr>
<td>Hexachlorobutadiene</td>
<td>all</td>
<td>Biotas standard</td>
<td>0.055</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EQS proposal</td>
<td>1.0</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BfR orientation value</td>
<td>0.5</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td></td>
<td>all</td>
<td>Biota standard</td>
<td>0.02</td>
<td>mg/kg FW</td>
</tr>
<tr>
<td>PFOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury/methylmercury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion factors:
1 mg = 1000 µg = 1,000,000 ng
1 kg = 1000 g = 1,000,000 mg

EU Regulation: EU Contamination Regulation No. 1881/2006 of 19 December 2006;
Kont-VO D = German ordinance to limit contaminants in food of 19 March 2010;
Biota standard = environmental quality standard for biota according to Directive No. 2008/105/EC;
RHmV = German ordinance on maximum quantities of residue \([Rückstandshöchstmengenverordnung]\) of 21 October 1999, most recently amended on 19 March 2010;
EQS proposal for PFOS according to the outcome of discussion of new candidate substances by the E 14 Working Group on 22 June 2011
BfR orientation value for PFOS according to statement by the Federal Institute for Risk Assessment (BfR) of 11 September 2008, see BfR 2008.

\(^{17}\) For DL-PCBs und dioxins: action levels
\(^{18}\) WHO TEQ of 1998
Appendix 4 shows the standards for assessing the results of studies on fish contamination in the Rhine States.

**Dealing with measurement uncertainties**

Before the measurement results are compared with the maximum levels (for example according to the EU Regulation), with measurements consequently being imposed regarding the marketability of fish, a defined percentage is usually deducted from the numerical measurement value to allow for measurement uncertainty. Different percentages are deducted in the various Rhine States (see Table 3).

In the EU Member States, the relevant provisions of Regulation (EC) No. 1883/2006 regarding dioxins, furans and DL-PCBs in food are applied to check whether maximum levels have been exceeded in the fish studied.\(^{19}\) The Regulation requires a first analysis to be used to determine whether maximum levels have been adhered to. A duplicate analysis is necessary to exclude the possibility of internal cross-contamination or an accidental mix-up of samples. There is a case of non-compliance if, after deduction of the measurement uncertainty from the results of the first analysis, the value is greater than the maximum level.

In the case of samples that are only slightly higher than the maximum, it is possible that different laboratories (regardless of national boundaries) have assessed the samples differently due to analytical fluctuations in the samples.

**Table 3: Percentages (+/-) of measurement uncertainty for various parameters in fish which are applied, depending on national legal frameworks and interpretation, to raw analytical data**

<table>
<thead>
<tr>
<th>Country/federal state</th>
<th>Dioxins/furans/DL-PCBs</th>
<th>NDL-PCBs/Indicator PCBs</th>
<th>HCB</th>
<th>Heavy metals</th>
<th>Organochlorine pesticides</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR</td>
<td>17.6% (dioxins) 20% (DL-PCBs)</td>
<td>22.7</td>
<td>15.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE-BW(^{20})</td>
<td>20%</td>
<td>20%</td>
<td>50%</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>DE-RP(^{21})</td>
<td>20%</td>
<td>20%</td>
<td>50%</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>DE-HE(^{22})</td>
<td>20%</td>
<td>25%</td>
<td>25%</td>
<td>5%</td>
<td>25%</td>
</tr>
<tr>
<td>DE-NW(^{23})</td>
<td>15%</td>
<td>15%</td>
<td>50%</td>
<td>10 – 20%</td>
<td>50%</td>
</tr>
<tr>
<td>NL(^{23})</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{19}\) EC Regulation No. 1883/2006, Annex I, Section 5
\(^{20}\) DE-BW: The measurement uncertainty for the organochlorine pesticides, including HCB – according to document No. SANCO/10684/2009 “Method Validation and Quality Control Procedures for Pesticide Residues in Food and Feed Analysis” – is basically given as 50% for all pesticides in foods of animal and vegetable origin, which corresponds to a single regime within the EU.
\(^{21}\) DE-RP: heavy metals: only Hg is measured
\(^{22}\) DE-NW: % in heavy metals according to analysis method in each case
\(^{23}\) NL: previously 15%
Unless indicated otherwise the presentation in the texts and figures in Section 3 (“Results”) and in Appendix 5 (“Measurements”), raw data is without the measurement uncertainty being subtracted; this is because the present report aims at an ecosystem approach and does not focus on the consequences under foodstuffs legislation of a maximum level being exceeded. The intention is also to ensure comparability of values as far as possible.

In many of the figures and in the text, reference is nevertheless frequently made to limits under foodstuffs legislation – and to those limits being exceeded – which were calculated using values after deduction of the above country-specific measurement uncertainty.

2.3 Fish species studied and criteria for selecting them

The fish species studied were selected primarily because of their availability and frequency in the section of the Rhine or tributary concerned. A number of institutions deliberately restrict their studies to only a single species or only a few species so as to increase the level of statistical certainty. Other institutions have investigated a wide variety of fish in accordance with the natural biodiversity, so as to optimise the likelihood of catching them and to cover all the proposed measurement locations, or to study a representative “basket of fish” containing the most important fish used for human consumption. Selection was also based on species-specific fat content or different habits (see 1.2).

When presenting the results, some studies distinguish between carp species (generally with a low proportion of fat, only occasionally a higher proportion of fat) and eel (in all cases a higher proportion of fat) or between fish used for human consumption and the remaining fish species. In France, a division of fish into strongly and weakly bio-accumulating species is usual.24

Appendix 3 shows which fish in which Rhine States were investigated for pollutants. The following table gives the characteristics of the most important fish species that were studied.

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24 AFSSA 2010
Tab. 4: Characteristics of the most important fish species studied

<table>
<thead>
<tr>
<th>Type of fish</th>
<th>Eel</th>
<th>Roach</th>
<th>Bream</th>
<th>Chub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific name</td>
<td>Anguilla anguilla</td>
<td>Rutilus rutilus</td>
<td>Abramis brama</td>
<td>Squalius cephalus</td>
</tr>
<tr>
<td>Table fish</td>
<td>yes</td>
<td>yes (regionally)*</td>
<td>yes (occasionally)*</td>
<td>yes (occasionally)*</td>
</tr>
<tr>
<td>Frequency in Rhine</td>
<td>hitherto high; declining</td>
<td>hitherto sufficient population density for sampling; declining in some sections of the Rhine; not in Upper Rhine</td>
<td>wide distribution but not common everywhere</td>
<td>wide distribution, normally present</td>
</tr>
<tr>
<td>Habitat</td>
<td>flowing and standing water, in particular in former channels with banks reinforced by dumping rock</td>
<td>flowing and standing water</td>
<td>prefers calmer areas with soft bed and former channels; flowing and standing water</td>
<td>adults also in standing water</td>
</tr>
<tr>
<td>Site fidelity</td>
<td>elvers: slight; yellow eel: high silver eel migrate downstream</td>
<td>moderate to high</td>
<td>high</td>
<td>slight to high</td>
</tr>
<tr>
<td>Primarily found</td>
<td>at bottom of water body</td>
<td>close to banks, in open water</td>
<td>at bottom of water body, bank-oriented</td>
<td>as juvenile, close to bank; as older fish, in open water</td>
</tr>
<tr>
<td>Contact with sediment</td>
<td>intensive</td>
<td>slight</td>
<td>intensive</td>
<td>slight</td>
</tr>
<tr>
<td>Food</td>
<td>pointed-nosed eel: benthic organisms; large-headed eel: fish, crustaceans, fish spawn**</td>
<td>macro-invertebrates, aquatic plants, plankton</td>
<td>benthic organisms; aquatic plants</td>
<td>macro-invertebrates, aerial insects, fish (small), amphibians, some aquatic plants and fruit; with increasing age, more fish</td>
</tr>
<tr>
<td>Lifespan</td>
<td>on average 10 to 15 years, sometimes more than 20 (occasionally 50) years</td>
<td>10 to 15 years</td>
<td>high (up to 25 years)</td>
<td>8 to 10 (15) years</td>
</tr>
<tr>
<td>Fat content</td>
<td>very high (&gt; 8%, up to 32%)</td>
<td>slight to moderate (up to 6%)</td>
<td>slight to high (up to 10%)</td>
<td>slight to high (up to 8%)</td>
</tr>
<tr>
<td>Bio-accumulation</td>
<td>high to very high***</td>
<td>slight to high***</td>
<td>slight to high***</td>
<td>slight to high***</td>
</tr>
</tbody>
</table>
Continuation of **Table 4: Characteristics of the most important fish species studied**

<table>
<thead>
<tr>
<th>Type of fish</th>
<th>Eel</th>
<th>Roach</th>
<th>Bream</th>
<th>Chub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous</td>
<td>regional catch restrictions because of threat to stocks and in contaminated areas</td>
<td>comparable with ICPR study in 2000</td>
<td>no catch restrictions because not endangered</td>
<td>no catch restrictions because not endangered</td>
</tr>
</tbody>
</table>

* The fact that they are so bony means that roach, bream, and chub are not popular as table fish. However, young fish (< 20 cm), in particular roach, are popular as fried fish, for example in South Germany and in the Benelux countries.

** There is greater development, as a percentage, of pointed-nosed eel and large-headed eel depending on the food supply in their habitat.

*** Age-dependent: with increasing age, all species of fish have a higher fat content.
3. Contamination of fish: results of studies in the Rhine States

3.1 Switzerland

**Dioxins, furans, DL-PCBs**

In Switzerland, 1300 records from the past 20 years were analysed as part of a report on the contamination of fish and water bodies with PCBs and dioxins. For most fish species and water bodies (including the Alpine Rhine and tributaries, the Aare to the mouth of the Sarine), the values for dioxin-like PCBs and dioxins are in a range of the background levels or slightly above. Significant violations of the maximum concentration laid down in food legislation (analogous to EU Food Regulation No. 1881/2006) were observed in fish from the Birs (a High Rhine tributary), the Sarine (an Aare tributary) and the Upper Rhine (see Figure 3). The high proportion of DL-PCBs was decisive for the violations of the maximum (see Figure 4).

Time series of PCBs in sediment cores from Swiss lakes and in breast milk show that contamination of the environment and of humans with PCBs has decreased significantly in recent decades but that the PCB residues in fish from certain water bodies necessitate further measures to eliminate PCBs.

**Outlook**

The locations where the food standards are exceeded are polluted by point sources (municipal waste tips with PCB contamination from the past). A monitoring programme covering not only fish but also sediments and measures to contain or remove sources of pollution (especially one known, large landfill on the Sarine) are currently being planned. Consumption recommendations (maximum weekly fish consumption) have been determined with a view to limiting exposure of the population through ingestion of PCDD/F and DL-PCBs.

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25 Schmid P. et al. 2010
Figure 3: PCDD/F and DL-PCBs contamination of fish in the Swiss section of the Rhine catchment area. Source: BAFU (Schmid et al. 2010)

Figure 4: Proportion of DL-PCBs and PCDD/F in contamination of various fish species in water bodies of the Swiss section of the Rhine catchment area. Source: BAFU (Schmid et al. 2010)
3.2 France

As part of the National PCB Action Plan, more intensive analysis has been carried out since 2008 in the French part of the Rhine catchment area in order to monitor fish species that are consumed by humans and to develop appropriate measures to contain possible health risks. Mercury, HCB and HCBD are analyzed in addition to PCBs.

**Dioxins, furans, DL-PCBs**

The food regulatory standards adopted by the EU for the sum of dioxins, furans and dioxin-like PCBs (PCDD/F DL-PCBs) are exceeded by a factor of 2 to 5 in most of the eel samples studied. In other species, the values were generally below the limit of 8 g/g FW. Interpretation of the analysis results for fish from the point of view of food legislation is carried out by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) after consultation with the Ministries of Agriculture and Health. The interpretation is published as a statement. The method used aims to assess the risk of long-term excessive exposure of fish consumers for every water system, with average contamination levels being compared with the maximum levels for the sum of dioxins, furans and DL-PCBs laid down in law. It is not the intention to test every single sample to determine whether it keeps within the limit. The statements issued may lead to the prefecture issuing a decree prohibiting fishing for consumption and the sale of fish.

**Mercury**

Studies of mercury levels were carried out on predatory fish, which were caught for the purpose of PCB analysis. Studies of samples of eel and pike (59 individuals) showed that in the case of two samples all the values were below the European food standard of 1 mg/kg FW. In the other species, the standard of 0.5 mg/kg FW was only exceeded in a single pike-perch and a single brown trout sample; these values still remained below 1 mg/kg FW. The EU biota standard of 0.02 mg/kg FW was systematically exceeded in all samples, however.

**Hexachlorobenzene and hexachlorobutadiene**

Of the 168 samples in which the level of HCB and HCBD was analysed, the standard for HCB of 0.01 mg/kg FW was exceeded in 38 eel samples (23%), with maximum values of up to 0.08 mg/kg FW, while the standard for HCBD was not found to be exceeded.

**Outlook**

A decree issued by the prefecture in 2009 prohibited consumption and marketing of eel – the most strongly accumulating species – from the French Rivers Ill and Andlau. In the French section of the Moselle (below the dam at Argancy) and in the Moselle tributaries, this prohibition applies to all species of fish.

Statements issued by ANSES can be found out [http://www.anses.fr](http://www.anses.fr).

The results regarding indicator PCBs, DL-PCBs, PCDD/F and PCDD/F+DL-PCBs are available at [http://www.pollutions.eaufrance.fr/pcb/](http://www.pollutions.eaufrance.fr/pcb/) (Excel and PDF).
3.3 Germany

In Germany, regional marketing prohibitions and consumption recommendations are based on the criteria set by the Federal Office of Consumer Protection and Food Safety (BVL) and the Federal Institute for Risk Assessment (BfR). Germany does not have a system of consumption prohibitions; such prohibitions would affect animal protection aspects because no vertebrate may be killed without good reason (for example consumption) and would therefore be equivalent to a prohibition on angling.

3.3.1 Baden-Württemberg

*Study programmes 2003 to 2008*

The ICPR’s Rhine fish research programme of 2000 recommenced in 2005/2006, with the number of measurement locations being reduced and the research being limited to eel and roach. In 2003, studies of a variety of fish species were carried out at one measurement location. In 2008, there were studies of eel at three measurement locations.

In each case, the range of analysis included a large number of persistent organic substances (see Appendix 2); only the assessment of dioxins, furans, dioxin-like PCBs, indicator PCBs, HCB and mercury will be considered below.
**Dioxins, furans, DL-PCBs**

In the High and Upper Rhine, a total of 20 samples of eel (single and composite samples) were investigated in 2005–2008 at six different measurement locations for dioxins, furans, and dioxin-like PCBs. In 17 of the 20 eel samples (85%), the maximum for the sum of dioxins, furans and dioxin-like PCBs (in WHO-PCDD/F-PCB-TEQ) was exceeded, taking into account a measurement uncertainty of approximately 20%. Two other eel samples exceeded the above-mentioned sum TEQ numerically, i.e. they fell within the measurement uncertainty.

The action level for the TEQ for DL-PCBs (6.0 ng/kg FW) was exceeded in all 20 eel samples (100%). Furthermore, the action level for the dioxin TEQ was exceeded in two eel samples.

Of four composite samples of other fish (bream, pike, roach, pike-perch) which were analyzed for dioxins, furans and dioxin-like PCBs, one (bream) exceeded the maximum for the sum TEQ.

**Indicator PCBs**

Investigation of 70 eel samples (single samples) at 9 different measurement locations for indicator PCBs (2005 to 2008) revealed two violations (2 eel = 3%) of the ordinance to limit contaminants (the former SHm-VO). Determination of the level of indicator PCBs in 21 composite samples of other fish (roach, perch, bream, chub, pike, pike-perch) did not reveal any cases in which the maximum was exceeded.

**Hexachlorobenzene**

Whereas in 2008 the maximum for HCB was no longer exceeded in any of the 15 eel studied, in 2005 that was still the case in 27% and in 2000 in 36% (total number of numerical and statistically significant cases in which the maximum according to the ordinance on maximum quantities of residue was exceeded).

Table 5 shows that since 1995 the proportion of eel in which the maximum was exceeded has decreased.

**Table 5: Numerically and statistically based cases of violation of maximum for indicator PCBs and HCB in Baden-Württemberg.** Number of eel with violations of the limit/proportion of eel with violations of the limit in total number of eel studied (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of samples</th>
<th>Indicator PCBs</th>
<th>HCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>41</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>2000</td>
<td>105</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>2005/2006</td>
<td>55</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2008</td>
<td>15</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Mercury**

Analysis of 70 eel samples and 21 composite samples of other fish for mercury showed no cases in which the maximum set in EU Contamination Regulation No. 1881/2006 was exceeded.
Study programme 2010: “Basket of fish”

In order to have the broadest possible spectrum of fish caught professionally and by anglers, two monitoring programmes were performed in Baden-Württemberg in 2010. These involved 46 samples of fish species relevant to human consumption (perch, grayling, pike, pike-perch, roach, whitefish, rudd, bream and brown trout) from the Rhine, Lake Constance, and other quarters. The samples were analysed for the following spectrum of substances: dioxins and DL-PCBs, NDL-PCBs, chlorine and organobromine pesticides and contaminants, nitro-musk compounds, pyrethroids and heavy metals, as well as perfluorinated tensides (PFTs). Selection of the water bodies, location of the sampling sites, selection of the fish types and species, and the size and age of the fish were according to their relevance to fishing (catch lists of professional fishermen, consumption relevance of each type of fish). Fat-rich fish with a fat content of more than 10% – which are more critical as regards accumulation of fat-soluble contaminants – were not among the fish sampled; such high fat content is generally only found in fillets of freshwater fish in the case of large, old individuals.26

Dioxins, furans, DL-PCBs

The applicable maximum for dioxins in fish was not exceeded in any of the samples analysed. The maximum for the sum of dioxins and dioxin-like PCBs was only exceeded (numerically) in a single bream sample from a reservoir (see Figure 3). That sample was a composite sample of two bream, each of which was more than seven years old (see 2.3). Some of the fish samples from the Rhine displayed levels of dioxin-like PCBs that were in the area of the established action level. By comparison, the findings from other water bodies were lower.

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26 A detailed report of the investigations can be found on the homepage of the Baden-Württemberg Research Agencies under CVUA Freiburg, Rückstände, Dioxine (www.ua-bw.de).
Fish monitoring 2010; PCDD/F + DL-PCBs

WHO-PCDD/F-TEQ
WHO-PCB-TEQ
WHO-PCDD/F-PCB-TEQ

Figure 6: Dioxins, DL-PCBs, and total dioxins + DL-PCBs (in pg WHO TEQ/g fresh weight), categorised according to water bodies and increasing Rhine-km in Baden-Württemberg. Source: CVUA Freiburg

Perfluorinated tensides
The highest concentrations of PFOS (perfluorooctanesulfonic acids) were found in fish from the Rhine (maximum value: 124 µg/g FW). In the samples from Lake Constance (lower lake), PFOS concentrations were an average of 15 µg/kg, whereas the mean PFOS content determined for freshwater fish in Germany is 22 µg/g FW (determined in the context of the control and inspection of foodstuffs in the period 2006–2008).27

Pesticides and heavy metals
In the case of pesticides, all the findings are well below the legal maximum. The highest level of mercury was found in the fish from the Rhine that were studied, with the level in those fish already being just below the maximum; in the other water bodies, the average accumulation is significantly lower.

Summary
Overall, considerable variation of the levels of dioxins, PCBs, pesticides, heavy metals, and PFT was identified in the samples. This can be explained, on the one hand, by the different pollution situation of the water bodies and the different species of fish and, on the other hand, by the extremely heterogeneous make-up of the composite samples. By focusing on the specific “basket of fish” produced by professional fishermen and anglers, the studies concerned provide a good estimate of the human intake of contaminants via freshwater fish. Given the nature of the sampling, however, the monitoring that was

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27 BfR 2008
carried out is not representative for the water bodies studied in the sense of environmental monitoring.

3.3.2 Rhineland-Palatinate

Monitoring of pollutants was carried out routinely until 2003 and in 2004 there was a measurement programme by ICPMS members for the Moselle and Saar rivers including tributaries (see 3.4). Single studies were carried out in 2006 and 2007. The report on the systematic study of fish along the course of the Rhine, Moselle and Saar in 2010 is currently in the course of production. Random sampling is also carried out in the framework of the official inspection of foodstuffs.

Dioxins, furans and PCBs, hexachlorobenzene, mercury

In the systematic studies in 2009 and 2010, it was possible to identify temporal and spatial trends compared to the data from 1991, 1992, 1995 and 2004 for indicator PCBs: in Palzem/Moselle, the concentration in eel fell to a fifth in the course of this period; in Schoden/Saar, however, it fell by only 20%. In roach and perch, this temporal trend can also be identified to a lesser extent. As previously, there is a fall in concentration down the Moselle, on which the inflow of the Saar is superimposed.

The results of the Rhine measurement programme of 2010 show a significantly lower concentration in eel (<30%) in a former arm of the Rhine connected only upstream at Otterstadt – which is affected by groundwater due to extensive dredging – as compared to eel from the Rhine itself. Similarly low values are found in bream, perch and young roach, pike and pike-perch. Large pike and pike-perch in the former arm of the Rhine also appear to catch prey in the Rhine itself; their contamination level is similar to fish from the Rhine itself. The pollutant content in perch and roach as well as in eel (standard method) displays a rising trend from the northern Upper Rhine to the Middle Rhine. The increase in pollution is very clear below the mouth of the Main but less clear below the mouths of the Neckar and the Moselle. The findings for the Nahe and Ahr are based on only a few fish studied which exceed the maximum level.

Sporadically, it was also established that the maximum levels for PCB 153, HCB, and mercury were exceeded.
Figure 7: Dioxins, furans and DL-PCBs (WHO TEQ) in eel from the Rhineland-Palatinate section of the Rhine in 2010. Source: LUWG

Figure 8: Dioxins, furans and DL-PCBs (WHO TEQ) in perch from the Rhineland-Palatinate section of the Rhine in 2010. Grey box: Fish length in cm/fat content in % (composite samples). Source: LUWG
Figure 9: Indicator PCBs in eel in Palzem/Moselle in various measurement years from 1991 to 2009. Source: LUWG

Figure 10: Indicator PCBs in eel in Schoden/Moselle in various measurement years from 1991 to 2009. Source: LUWG

Outlook

Based on the study results, the marketing of eel was prohibited. A recommendation not to eat eel had already been issued in 2006 because that fish can basically be assumed to contain too high a level of PCB contamination. A consumption recommendation for other fish species was issued in April 2010 as an updated information sheet giving the following maximum consumption quantities:
Table 6: Consumption recommendations for fish from the Rhine and its tributaries in Rhineland–Palatinate

<table>
<thead>
<tr>
<th>River</th>
<th>Fish species/group</th>
<th>Size</th>
<th>Portions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahr, Lahn</td>
<td>Carp species</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Rhine</td>
<td>Carp species</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nahe</td>
<td>Carp species</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Moselle</td>
<td>Roach</td>
<td>&lt; 20 cm</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Barbel, bream, chub</td>
<td>&gt; 40 cm</td>
<td>½**</td>
</tr>
<tr>
<td></td>
<td>Wels catfish</td>
<td>&gt; 40 cm</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Perch</td>
<td>on average 20 cm</td>
<td>8</td>
</tr>
<tr>
<td>Saar</td>
<td>Roach</td>
<td>on average 20 cm</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Wels catfish</td>
<td>50 – 60 cm</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Perch</td>
<td>&lt; 20 cm</td>
<td>8</td>
</tr>
</tbody>
</table>

* maximum allowable number of 200 g portions per month  
** maximum of one 200 g portion in 2 months  

See information sheet for anglers in Rhineland-Palatinate, April 2010, http://www.wasser.rlp.de/servlet/is/2027/

In addition, a programme of biota trend monitoring based on EU Directive 2008/105/EC (EQS) is also planned, taking account of the WFD survey measurement locations. Fish samples from the impounded sections at Koblenz and Palzem (Moselle) and at Schoden (Saar) will also be taken into consideration. Currently, the intention is to carry out studies every six years, commencing in 2010 or 2011.

3.3.3 Hesse
In 1999 and 2000, the Hesse Institute for Environment and Geology (HLUG) studied a total of 6 eel samples for various environmental chemicals and 7 perch and 2 roach samples for organotin compounds. The permissible limits for hexachlorobenzene, PCB 138, PCB 153 and PCB 180 were exceeded in 4 eel samples. The results are available on the Internet at http://www.hlug.de/medien/wasser/messwerte.htm (title of study: "Belastungen von Fischen mit verschiedenen Umweltchemikalien in Hessischen Fließgewässern").

In 2009, the Hesse Federal State Laboratory (LHL) carried out a study in fish from 4 measurement locations in the Rhine of environmental pollutants relevant from the point of view of foodstuffs legislation. Three of the measurement locations were in former branches of the Rhine. The Rhine constantly flows through the Erfeld and Ginsheim branches, but the Lampertheim branch is only subject to the fluctuations in the level of the river, and the Rhine only flows through it when the level is very high. None of the three former branches of the Rhine is affected by groundwater. The fourth sampling location is in the harbour at Rüdesheim. The outcome of this study is dealt with below.
### Table 7: Fish from the Rhine in Hesse 2009

<table>
<thead>
<tr>
<th>Catch location</th>
<th>Type of fish</th>
<th>Number of fish</th>
<th>OCP/ND L-PCB</th>
<th>DXN/D L-PCB</th>
<th>PFT</th>
<th>HME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lampertheim arm of Rhine</td>
<td>Eel</td>
<td>1 X</td>
<td>X X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(km 440)</td>
<td>Perch</td>
<td>50 (small) X</td>
<td>X X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Wels catfish (2 samples)</td>
<td></td>
<td>2 x 1</td>
<td>X X X X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erfeld arm of Rhine</td>
<td>Orfe</td>
<td>1 X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(km 473)</td>
<td>Perch</td>
<td>4 X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roach</td>
<td>1 X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ginsheim arm of Rhine</td>
<td>Eel</td>
<td>2 X</td>
<td>X X X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(km 490)</td>
<td>Perch</td>
<td>4 X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tench</td>
<td>1 X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wels catfish</td>
<td>1 X X X X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rüdesheim harbour</td>
<td>Eel</td>
<td>2 X</td>
<td>X X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(km 525)</td>
<td>Orfe</td>
<td>1 X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perch</td>
<td>4 X</td>
<td></td>
<td>X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roach</td>
<td>21 X X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **OCP/NDL-PCBs** = investigation of organochlorine pesticides and non-dioxin-like PCBs
- **DXN/DL-PCB** = investigation of dioxins and non-dioxin-like PCBs
- **PFT** = investigation of perfluorinated tensides
- **HME** = investigation of heavy metals (lead, cadmium, mercury)

### Dioxins, furans, DL-PCBs

Only eel and wels catfish were investigated. Neither the action level nor the maximum for the TEQ for dioxins were exceeded, in either species. The action level for the TEQ for DL-PCBs was exceeded in the eel and in two wels catfish even after deduction of the measurement uncertainty of +/-20%. The proportion of DL-PCBs is also responsible for the violations of the maximum levels of TEQ for the sum of dioxins and DL-PCBs in the eel and in 2 wels catfish. After deduction of the measurement uncertainty, the sum TEQ only exceeds the permissible maximum in the eel.
**Organochlorine pesticides**

The permissible maximums in the ordinance on maximum quantities of residue was found to be exceeded in only one case. In an eel from the Ginsheim arm of the Rhine, the quantity of beta-HCH (0.141 mg/kg fat) was slightly above the limit of 0.1 mg/kg fat after deduction of the measurement uncertainty (+/-25%).

**Indicator PCBs**

No violation was observed of the permissible maximums for the individual NDL-PCB congeners as set out in the contaminants ordinance. The maximums currently under discussion by the EU for the sum of 6 indicator PCBs in fish muscle tissue (see 2.2) were exceeded, however, in 2 of the eel samples studied (Rüdesheim harbour: 0.393 mg/kg FW; Ginsheim former arm of Rhine: 0.350 mg/kg FW). After deduction of the measurement uncertainty, however, none of these samples exceeded the maximum.
Perfluorinated tensides

All the samples were investigated for 10 perfluorinated tensides. PFOS (perfluorooctanesulfonic acid, maximum = 126 µg/kg FW) was identified most frequently and in the highest concentrations. To a lesser extent, the substances PFDA (perfluorodecanoic acid; maximum value = 11 µg/kg FW) and PFDOA (perfluorododecanoic acid; maximum value = 6.5 µg/kg FW) and PFOA (perfluorooctanoic acid, maximum value = 3.3 µg/kg FW) were detected. The values for the other compounds were below the detection limit in all the samples.
Heavy metals
The permissible maximum set in the EU Regulation on maximum levels for lead, cadmium, and mercury was found to be exceeded in only one case. In a wels catfish from the Lampertheim arm of the Rhine, the quantity of mercury (0.577 mg/kg FW) exceeded the limit of 0.5 mg/kg FW after deduction of the measurement uncertainty (+/-5%).

Outlook
The known high level of contamination of eel with dioxin-like PCBs was confirmed by the studies. PFTs today represent another problem as regards the contamination of fish. The studies did not lead to any prohibitions on marketing or consumption because the fish concerned are not in fact intended for marketing.

3.3.4 North Rhine-Westphalia
As part of annual residue testing of fish from the Rhine, an extensive list of contaminants has been analysed since 2000 at varying measurement locations. The objective of the measurement programme was to survey the contamination situation and to answer a number of specific questions. In 2008 and 2010, measurements were carried out in order to implement EU Directive 2008/105/EC at the survey measurement locations on the Rhine and at the mouths of the tributaries (2008: 46 fish investigations at 9 measurement locations for the parameters of lead, cadmium and mercury; 2010: for hexachlorobenzene and hexachlorobutadiene).
Dioxins, furans, DL-PCBs
Violations of the maximum for the sum of dioxins, furans, and dioxin-like PCBs were identified in 2008 to 2010; they were based on a high proportion of DL-PCBs in the samples studied. Violations of the maximums for dioxins were only sporadic.

Indicator PCBs
Six indicator PCBs were investigated in eel taken from the Rhine in 2002 and 2005. Violations of the maximums permitted under foodstuffs legislation were determined for PCB-101, PCB-138, and PCB-153.

Hexachlorobenzene and hexachlorobutadiene
In 2010, the EQS of 0.01 mg/kg FW for HCB and 0.055 mg/kg FW for HCBD was achieved in all the fish samples (muscular tissue) analysed from the Rhine measurement locations in 2010. Where the trend in HCB contamination is concerned, there would appear to be a reduction in the quantity in relation to fat content. This trend requires statistical confirmation, however. The extent to which statements regarding trends for other parameters are possible on the basis of the available data is still under investigation.

Perfluorinated tensides
In the period from 2006 to 2009, PFOS was investigated in muscle samples from 100 fish (13 different species from the Rhine that are used for human consumption). The findings were between 3.1 µg/kg and 71 µg/kg (median 16.7 µg/kg).

Table 8: Investigation of Rhine fish for PFOS in North Rhine-Westphalia.
a. Data on sampling; b. results

<table>
<thead>
<tr>
<th>River</th>
<th>River km</th>
<th>Number of measurement locations in Rhine</th>
<th>Period</th>
<th>Number of fish species</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhine</td>
<td>640 to 781</td>
<td>5</td>
<td>2006 to 2009</td>
<td>13</td>
<td>100</td>
</tr>
</tbody>
</table>

b.

<table>
<thead>
<tr>
<th>Average PFOS level µg/kg</th>
<th>Minimum PFOS µg/kg</th>
<th>10 percentile PFOS µg/kg</th>
<th>Median PFOS µg/kg</th>
<th>90 percentile PFOS µg/kg</th>
<th>Maximum PFOS µg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.2</td>
<td>3.1</td>
<td>8.2</td>
<td>16.7</td>
<td>48.0</td>
<td>71.0</td>
</tr>
</tbody>
</table>

Testing was also carried out at other measurement locations throughout the network of waterways in North Rhine-Westphalia. The figure below compares the results for the survey measurement locations in the Rhine catchment area and for the Rhine measurement locations. It shows that fish from the measurement locations on the Rhine are on average contaminated to a greater extent than those from most other water bodies. However, fish from certain water bodies (for example the Lenne and the middle section of the Ruhr) display even higher contamination.
PFOS content of fish at survey measurement locations in the Rhine catchment area in NRW, 2006-2009

Averages (n≥8) with standard deviation

Figure 14: Investigations of PFOS content in fish at survey measurement locations in the Rhine catchment area in North Rhine-Westphalia. Comparison of contents in the Rhine and in tributaries. The averages (n ≥ 8) are shown for each catch location for the period 2006–2009, with the standard deviation.

The results correlate with the PFOS contaminations in water, which are in the nanogram area, whereas PFOS in fish are accumulated by a factor 1000 (see 1.2 and Appendix 6, where the calculation of bio-accumulation factors for PFOS in fish is presented in full).28

**Mercury**

The Environmental Quality Standard for mercury according to the biota standard specified in Directive 2008/105/EC was exceeded at all the survey measurement locations in 2008. Violations were also identified of the EU Contaminants Regulation No. 466/2001 or EU Regulation No. 1881/2006 and the Pollutants Limits Ordinance.

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28 See LAWA 2010
Table 9: Violations of limits for individual pollutants at measurement locations in the Rhine catchment area in North Rhine-Westphalia according to EU Food Regulation No. 1881/2006 (EU Reg.) or the Environmental Quality Standard for biota according to Directive No. 2008/105/EC ("Biota standard")

<table>
<thead>
<tr>
<th>Substance</th>
<th>Year</th>
<th>Standards exceeded</th>
<th>Violations and individual measurement locations/details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cadmium</td>
<td>2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mercury</td>
<td>2008</td>
<td>X*</td>
<td>Bad Honnef</td>
</tr>
</tbody>
</table>

| PCDD/F    | 2002 | -                   | X                                                     |
|           | 2003 | -                   | X                                                     |
|           | 2004 | -                   | -                                                     |
|           | 2008 | -                   | -                                                     |
|           | 2009 | -                   | X                                                     |

<table>
<thead>
<tr>
<th>Dioxins + DL-PCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
</tr>
<tr>
<td>2009</td>
</tr>
</tbody>
</table>

| ND-PCBs | 2002 | -     |
| PCB 101 | 2002 | -     |
| PCB 138 | 2003 | -     |
| PCB 153 | 2003 | -     |
| PCB 180 | 2003 | -     |
| HCB     | 2010 | -     |
| HCB/HCBD | 2010 | -     |

| PCB 101 | 2003 | -     |
| PCB 138 | 2003 | X     |
| PCB 153 | 2003 | X     |
| PCB 180 | 2003 | X     |
| NDL-PCBs | 2005 | -     |
| PCB 101 | 2005 | -     |
| PCB 138 | 2005 | -     |
| PCB 153 | 2005 | -     |
| PCB 180 | 2005 | -     |
| DDT     | 2005 | -     |
| Musk xylene | 2005 | -     |
| Musk ketone | 2005 | -     |

| PFOS     | 2006–2009 | - | - |

*Violations at all survey measurement locations
**Also violation of Pollutants Limits Ordinance
Outlook

Elevated dioxin and PCB contamination already led in 28 March 2003 to the Ministry for Consumer Protection of the German State of North Rhine-Westphalia issuing a recommendation to refrain from eating eel from the Rhine.

Investigations in the framework of the food monitoring project (LM-PM) and the fish inspection programme (LUP) were continued. In the context of implementation of Directive 2008/105/EC, a trending investigation programme will be added to the investigation programme for monitoring Environmental Quality Standards.

3.3.5 Bavaria

As part of the Bavarian programme for monitoring contaminants in fish, the State Agency for Environmental Protection (LfU) carries out an annual survey at 16 measurement locations in the catchment area of the Main. Its aim is to improve the health of fish, to identify substances in water bodies, to trace the causes of pollution, to implement measures, to clarify long-term trends, to document remediation successes, and to make recommendations should permissible limits under food legislation be exceeded. A large range of fish species are sampled. The heavy metal concentrations in muscle tissue and the spleen are determined for 3 to 6 individual fish per sampling location, as well as the levels of as well as the levels of HCB, HCBD, indicator PCBs, 1,2,4-trichlorobenzene and pentachlorobenzene in muscle tissue and the liver. At a number of locations, analysis is also carried out for other substances (DEHP, HHCB, nonylphenol, octylphenol, triclosan, methyl triclosan). Some of the fish samples taken in the years 2009/2010, mainly of eel, will also be reanalysed, as in 2002 and 2003, for DL-PCBs.

The State Agency for Public Health and Food Safety (LGL) also investigated fish that is marketed as a food, particularly originating from fish farming, for such aspects as the residue levels of organochlorine compounds (indicator PCBs, HCB) and heavy metals. Since 2002, fish samples have also been regularly analysed to determine the level of dioxins and furans; since 2006 this has also been done for PFTs and since 2007 for dioxin-like PCBs. If not otherwise indicated, the results described below refer to 11 eel samples taken in 2009 from the catchment area of the Main.

Dioxins, furans, DL-PCBs

The maximum levels for dioxins, furans, and DL-PCBs (WHO-PCDD/F-PCB) were exceeded in all 8 eel samples from the catchment area of the Main in 2002. The totals (WHO-PCDD/F-PCB-TEQ) varied from 31.1 to 77.7 pg/g FW. In the 4 samples from other species, the maximum level for dioxins, furans, and DL-PCBs was exceeded numerically in a silver bream with a WHO-PCDD/F-PCB-TEQ of 8.3 pg/g FW, meaning that it remained within the measurement uncertainty of approx 20%.

The maximum levels for dioxins, furans, and DL-PCBs were exceeded in 6 of the 7 eel samples taken by the LfU in 2003. The totals (WHO-PCDD/F-PCB-TEQ) varied from 4.6 to 46.3 pg/g FW. The 5 samples from other species were unremarkable.

The maximum levels for dioxins, furans, and DL-PCBs were exceeded in all 11 of the eel samples taken by the LGL in 2009. The totals (WHO-PCDD/F-PCB-TEQ) varied from 16.2 to 60.7 pg/g FW.

Indicator PCBs

The foodstuffs limits for indicator PCBs were sporadically exceeded in samples taken by the LfU (approx. 65 fish annually) from the Main and Schwarzach. No violations of the maximum levels were found in the tests carried out by the LGL (11 eel in 2009) for indicator PCBs.
The LFU only found violations of the HCB biota standard (10 ng g/FW) according to Directive 2008/105/EC in the Main and its catchment area in the muscle tissue of eel. HCB levels of > 10 ng/g FW were also only measured sporadically in the liver of nase, pike and dace. Muscle and liver samples from other species all displayed an HCB level of < 10 ng/g FW.

Heavy metals
Since 2005, the EQS for mercury in biota according to Directive 2008/105/EC has been regularly and largely significantly exceeded at all of the LFU’s measurement locations. Measurements were made of both chub and bream, and also of other species. The foodstuffs limits for mercury and lead were only exceeded very sporadically.

Outlook
Investigations in the framework of the Bavarian system for monitoring contaminants in fish will continue. Changes are planned in the sampling strategy and the range of materials investigated with a view to surveillance monitoring according to the WFD and the EQS for biota. Statistical analysis of data from the past 10 years has yet to be effected. All expectations are that the trend for the substances investigated will be downward or stable.

A condensed version of the reports from the LFU’s most recent reporting period (2005 and 2006) is available at


The contaminant combination dioxins, furans, and dioxin-like PCBs was first measured by the LGL in 2009. It is not therefore possible to make any statement regarding a trend. Given the limit violations that have been observed, further investigations are planned for fish from the Main for 2010. Fish that are marketed for human consumption will also be investigated.

Overview data for these investigations are available in the LGL’s annual reports: [http://www.lgl.bayern.de/publikationen/jahresberichte.htm](http://www.lgl.bayern.de/publikationen/jahresberichte.htm)
All the individual data is reported to the database operated by the federal government and the federal states and can be viewed there: [http://www.pop-dioxindb.de](http://www.pop-dioxindb.de)
3.3.6 Saarland
In 2009 and 2010, fish (primarily chub but in Saarlouis bream) from the Saar and its tributaries and from the Moselle were investigated for contaminants.

**Dioxins, furans, PCBs**
The limit specified in the relevant EU regulation (8 pg/g PCDD/F-PCB WHO TEQ) was exceeded in 4 samples. In all cases, this was due to raised levels of PCBs. The highest levels of both NDL-PCBs and DL-PCBs were found in a bream from the Saarlouis sampling location on the Saar.

**Perfluorinated tensides**
Only PFOS and to some extent PFHxS were detected in significant quantities, namely in bream, crucian carp, and roach or carp in two ponds at Sankt Wendel, which were contaminated with extinguisher foam after a major fire in May 2007. The samples from the watercourses definitely keep to the guidance value of 30 µg /kg.29

**Mercury**
Nine of the 10 samples investigated were below the limit for foodstuffs of 500 ng/g FW; it was only in a chub from the sampling location at Reinheim (on the Blies) that a slight violation (520 ng/g FW) was identified.

**Outlook**
The results for dioxins and PCBs deviated greatly from the much lower values from the previous years and resulted in a consumption recommendation being issued in July 2010, advising against consumption of fish caught in the Saar downstream of the barrage at Saarbrücken-Burbach.

3.3.7 Federal Environmental Specimen Bank
The Federal Environmental Specimen Bank (UPB) collects samples from the environment and from humans and stores them for the long term so as to provide ecotoxicological and toxicological evidence. Before being stored, all samples are analysed for a specific set of inorganic and organic substances ("real-time monitoring"); the data can be accessed via the UPB’s website www.umweltprobenbank.de.30

**Dioxins, furans, DL-PCBs**
In 2008, the permissible maximum (4 pg/g FW) for dioxins/furans was only exceeded in bream from the measurement location at Bimmen. At that location, there was a rising trend in dioxin content between 1995 and 2000. Between 1995 and 2005, bream from the measurement location at Weil displayed dioxin concentrations that were up to a factor of 3 higher than the maximum level. Concentrations decreased abruptly from 2006 on because since then it has only been relatively young bream that could be caught at the Bimmen measurement location. Dioxin levels in fish from the Iffezheim measurement location have remained fairly constant over the years, namely at or just under the limit. Bream from the Koblenz measurement location were only slightly contaminated with

29 At an average consumption of 300 g of fish per day and a body weight of 60 kg, the TDI of 0.15 µg of PFOS per kg body weight and day proposed by the BfR would be used up with a contamination of 30 µg/kg.
30 Data can be provided as Excel files on request. Data on dioxins, furans, and DL-PCBs is not uploaded to the UPB’s database but to the dioxin database of the federal government and the federal states. The results can be provided on request in the desired form (WHO-PCDD/F-TEQ, WHO-PCDD/F-DL-PCB-TEQ).
dioxins in 2004; shifts in the fish sampled towards older and more fat-rich individuals led to dioxin concentrations of around the limit.

In 2008, the maximum (8 pg/g FW) for dioxins/furans/DL-PCBs – calculated as WHO-PCDD/F-PCB-TEQ – was exceeded in bream from Iffezheim, Koblenz, and Bimmen (see Figure 15).

Trends over time of total TEQ in bream from the 4 Rhine measurement locations basically correspond with those of the PCCD/F-TEQ, with the difference that the inclusion of DL-PCBs more frequently leads to the maximum being exceeded.

![Figure 15: Trend over time in contamination of bream from the Rhine itself with dioxins, furans, and DL-PCBs. Source: UBA](image)

**Indicator PCBs**

Indicator PCB concentrations in the muscle tissue of bream from all the Rhine locations are clearly below the current maximum levels according to the ordinance on the maximum quantities of pollutants. If the EU value that is currently under discussion of 110 ng/g FW for the sum of the 6 indicator PCBs (see 2.2) is introduced, bream from the measurement locations at Iffezheim, Koblenz, and Bimmen would be unfit for human consumption. As regards fresh weight, there were widely varying values over the observation period from 1995 to 2009, with rising trends in concentrations in fish from Iffezheim, Koblenz, and Bimmen. Where fat content is concerned, the curves level off, but here too no significant consistent decrease in PCBs has been observed in bream since 2000.

---

31 200 ng/g FW each for PCB congeners 28, 52, 101, 180 and 300 ng/g FW each for PCB congeners 138 and 153
Hexachlorobenzene

HCB concentrations in the muscle tissue of bream from the Rhine locations of Weil, Koblenz, and Bimmen are around or below the HCB biota standard according to Directive 2008/105/EC (10 ng/g FW). At Iffezheim, the standard was exceeded by a factor of up to 5 from 1999 to 2008; in 2009, the HCB concentrations measured were only slightly higher than the standard. Since there were hardly any differences between the bream sampled at Iffezheim with respect to age, weight and fat content, this finding may indicate a sustained decrease in HCB contamination at that location.

![Graph showing HCB concentrations in bream from Rhine locations](image)

**Figure 16: Hexachlorobenzene contamination of bream from the Rhine itself (source: UBA)**

Mercury

Mercury concentrations in the muscle tissue of bream from all Rhine sampling locations were significantly higher than the biota standard for mercury according to Directive 2008/105/EC, namely 0.02 mg/kg FW; that standard was exceeded by 5 to 17 times. No decreasing trend in mercury concentrations can be observed for the period from 1995 to 2009. The abrupt drop in the mercury concentration at Weil between 2005 and 2006 is explicable by the fact that only relatively young bream could be sampled there in recent years.
Figure 17: Mercury contamination of bream from the Rhine itself (source: UBA)

Outlook
The long-term studies by the Environmental Specimen Bank of contaminant levels in bream show that assessment of trends in concentrations over time must always take account of the age and fat content of the fish sampled. This reveals the limits of standardisation of sampling when, for example, “old” bream populations can no longer be sampled at Weil or when fish become more fatty due to improved living conditions. This phenomenon has been observed in the context of the Environmental Specimen Bank not only in the Rhine but also in other watercourses.

3.4 Moselle-Saar area
In the spring of 2004, an international programme for monitoring suspended matter and fish for dioxins, furans and PCBs, including the WHO-PCBs, was carried out throughout the catchment area of the Moselle and Saar.\textsuperscript{32} The programme revealed that the analysis results are distributed more unequally spatially for pollutants in fish than for pollutants in suspended matter. They differ for eel and carp species, with some locations displaying very high levels that have no equivalent in the results for suspended matter. The distribution of congeners also varies greatly. Comparison of the results for fish with the limits and guidance values revealed clear violations in eel from virtually all measurement locations. The values for carp species also displayed violations of the guidance values in individual cases.

\textsuperscript{32} International monitoring programme for "PCBs and related substances in suspended matter and fish in the Moselle and Saar 2004", ICPMS, see http://www.iksms-cipms.org => Publikationen => Inter_Messprogrammem_Schwebstoffe_Fische_2004.pdf
Figure 18: Contamination of eel from water bodies of the Moselle-Saar catchment area with dioxins, furans, and PCBs. Source: ICPMS report 2005

Figure 19: Contamination of carp species from water bodies of the Moselle-Saar catchment area with dioxins, furans, and PCBs. Source: ICPMS report 2005
3.5 Luxembourg

In 2000, 2002 and 2003, fish from the Sûre and its tributaries were investigated with the following aims: (1) to identify contamination of fish with persistent, bio-accumulating pollutants as completely as possible; (2) to determine geographically the potential sources for the pollutants measured; and (3) to be able to estimate the risks to health from consuming fish from Luxembourg watercourses.

**Dioxins, furans, DL-PCBs**

The samples of eel all displayed major violations of the EU limit of 12 pg/g FW; the extreme values were between 21 pg/g FW and 160 pg/g FW. In the case of carp species (various species), the EU limit of 8 pg/g FW was only sporadically violated; the extreme values were from 0.43 pg/g FW to 10 pg/g FW.\(^{33}\)

The following watercourses are considered to be contaminated with PCBs: the Moselle, the Middle and Border Sûre, the lower Our and the Wiltz, and also – to a lesser extent – the Alzette, the Clerve, and the Syre. Besides the man-made lake on the upper Sûre, the following watercourses are the least contaminated with PCBs: the Upper Sûre (especially below the man-made lake), the Eisch, the Mamer, the upper Our, the Attert, and the Wark.

Compared with previous surveys in 1993/1994 and 1998/1999, no trend in contamination over time could be detected; it is therefore assumed that the main sources of pollution are of a chronic and persistent nature.

**Outlook**

There is no commercial fishing in Luxembourg, and Luxembourg fish are therefore not marketed. Nevertheless, the survey in 2003 led to a consumption recommendation being issued; this was updated in 2010: [http://www.securite-alimentaire.public.lu/actualites/communiques/2011/06/pcb_consummation_poissons/index.html](http://www.securite-alimentaire.public.lu/actualites/communiques/2011/06/pcb_consummation_poissons/index.html). The recommendation advises people not to eat eel and recommends only moderate consumption of carp species in accordance with the WHO-TWI of 14 pg/g TEQ per kg of bodyweight.

3.6 Netherlands

Up to 2006, the Netherlands carried out a programme for monitoring the quality of water and ecosystems. In particular, eel were studied to determine the presence of persistent organic pollutants (POPs) – the concentration of which in water is very low – in the environment. HCB and mercury, which accumulates in organisms as methylmercury, have also been measured in eel since 1977. The concentrations in eel are compared in the reports with values for MTR and HC\(_5\). The angling monitoring programme conducted on behalf of the Ministry of Agriculture, Nature and Food Quality focused on the quality of eel (and some pike-perch) as food. The fish were tested for, amongst other things, PCBs, certain organochlorine pesticides (OCPs), and mercury. Substances were also investigated for which there were no statutory standards. Since the EU Directive came into force, dioxins, furans, and DL-PCBs in eel have also been analysed. Other surveys of eel have also been carried out.

\(^{33}\) The values from older investigations have been converted to WHO TEQ. The surveys in 2000 to 2003 involved dry matter; the relevant values have been converted to fresh weight.
At a number of measurement locations, fish have been investigated since 1980. The following figures display the trends for the most important substances/groups of substances compared to the relevant limit.

**Dioxins, furans, DL-PCBs**

Since EU Regulation No. 1881/2006 came into force, the EU limit of 12 ng/kg FW TEQ for dioxins, furans, and DL-PCBs for eel has been consistently exceeded in the Dutch section of the Rhine catchment area. In the western section, violations of the limit are considerable, with even small (thin) eel displaying high TEQ levels. In large eel, maximum TEQ values of more than 80 ng/kg had been measured.

![Figure 20](image-url)  
**Figure 20:** Contamination of yellow eel from the Delta Rhine (NL) with dioxins, furans, and dioxin-like PCBs in the period 2001–2009. Sum parameter PCDD/F + DL-PCB TEQ. Yellow eel with a length of 30 to 40 cm, composite samples of 25 individuals. Source: RIKILT/IMARES reports 1993 to 2010

**Indicator PCBs**

In the 1980s, the then applicable limits under Dutch food legislation were regularly exceeded, particularly that for PCB 153 (500 µg/kg). These violations have become less frequent. It is only in the lower reaches of the Rhine (sedimentation area) that the contamination level is still comparably high, especially in large fat-rich eel.
Figure 21: Contamination of yellow eel from the Delta Rhine (NL) with indicator PCBs in the period 1978–2009. Sum of 6 indicator PCB congeners. Yellow eel with a length of 30 to 40 cm, composite samples of 25 individuals. Source: RIKILT/IMARES reports 1993 to 2010.\textsuperscript{34}

**Hexachlorobenzene**

The following figure shows the HCB concentration at measurement locations in the Dutch section of the Rhine catchment area compared to the biota standard according to Directive 2008/105/EC. This is almost achieved for HCB (limit: 10 µg/kg). In recent years, concentrations have been between 11 µg/kg and 16 µg/kg. The HCB concentrations in eel from Lake IJsselmeer have in fact been below the biota limit since 1990.

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\textsuperscript{34} Source for Figures 14 to 16: RIKILT/IMARES reports 1993 to 2010. The studies were financed by the Ministry of Agriculture, Nature and Food Quality and by the Directorate General for Public Works and Water Management [Rijkswaterstaat].
Figure 22: Contamination of yellow eel from the Delta Rhine (NL) with HCB in the period 1977–2009. Yellow eel with a length of 30 to 40 cm, composite samples of 25 individuals. Source: RIKILT/IMARES reports 1993 to 2010

**Perfluorinated tensides**

In 2007, 15 perfluorinated compounds were investigated in eel, water, and sediments in Dutch water bodies. For 3 measurement locations, new analytical methods were also used to investigate PFOS in eel samples taken over the course of the past 30 years. Between 1978 and the mid-1990s, the concentration of PFOS in the samples doubled or even quadrupled, then returning to the baseline values (see Figure 23). In recent samples, PFOS was the predominant compound amongst the PFTs; the PFOS concentrations in the muscle tissue of eel were between 7 ng/g FW and 58 ng/g FW.
PFOS concentrations in eel filet between 1978 - 2008

Figure 23: PFOS concentrations in eel (n = 25) in Delta Rhine between 1997 and 2008.
Source: Kwadijk et al. 2010

**Mercury**

As Figure 24 shows, concentrations of mercury/methylmercury in eel have decreased since the 1980s. Since 2000, no further improvement has been determined at the majority of measurement locations. The biota standard of 0.02 µg/kg FW is systematically exceeded throughout the Dutch section of the Rhine catchment area.
Figure 24: Contamination of yellow eel from the Delta Rhine (NL) with mercury in the period 1977–2009. Yellow eel with a length of 30 to 40 cm, composite samples of 25 individuals. Source: RIKILT/IMARES reports 1993 to 2010

**Outlook**

Other Dutch food standards are not exceeded. In September 2000, the Ministry of Agriculture, Nature and Food Quality recommended that anglers should not consume eel that they caught in the country’s major rivers because of the analysis results for PCDD/F + DL-PCBs. For the past few years, anglers have also been required to release eel that they catch. Since 1 April 2011, fishing for eel in all areas contaminated with dioxins (TEQ) has been prohibited. The areas concerned are designated on the basis of the investigation results, and include all the major rivers of the Netherlands. The prohibition also includes a ban on the use of 10 specific types of gear used to catch eel; possession of eel in the areas concerned and their immediate vicinity is also prohibited. The prohibition on fishing for eel applies to everyone, not just professional fishermen but also anglers.35

In the view of the Netherlands, coordinated monitoring of pollution concentrations in biota should continue. Not all OCPs are still relevant; some (for example lindane) were taken off the market long ago, meaning that their concentrations have quickly diminished to well below the applicable standards. PCB concentrations in eel remain high, however, constituting 70% to 90% of the total TEQ values in eel in Dutch water bodies. PFTs, in particular PFOS, should continue to be monitored despite the downward trend; here, eel are a suitable bio-indicator.

35 Kotterman & van der Lee 2011
4. Assessment of the ICPR’s suspended matter measurement programme as regards PCB 118

In the course of the international Rhine chemicals measurement programme, the sole dioxin-like PCB measured since 1991 has been PCB 118. The sampling frequency is 13 to 26 samples annually, meaning that the calculated annual averages are representative for the PCB pollution of the Rhine. The PCB levels of suspended matter are representative for the PCB pollution of recent sediments. Since 2000, the PCB 118 levels in suspended matter have not decreased as much as in the 1990s. The accumulation of PCBs over the course of the Rhine is also not as marked as it was back then.

At the measurement location at Weil on the German-Swiss border, the annual average level of PCB 118 has been approx. 1 µg/kg. Fluctuations have been only slight; the maximum levels are 2 µg/kg to 2.5 µg/kg.

At the three other measurement locations (Lauterbourg/Karlsruhe, Koblenz, Bimmen), average levels decreased by half between 1994 (4 µg/kg) and 2007 (2 µg/kg to 2.5 µg/kg). Levels at Bimmen on the German-Dutch border are partly well above the levels at Koblenz and Karlsruhe.

![Levels of PCBs 118 in suspended matter in the Rhine (annual average)](image)

**Figure 25:** Levels of PCB 118 in suspended matter in the Rhine (annual average, levels in µg/kg).

*Source: ICPR suspended matter measurement programme 1991–2007*
5. Summary of results for the Rhine catchment area

The following subsections provide a survey of the contamination of fish from the Rhine and its tributaries with dioxin-like PCBs and other pollutants on the basis of the combined data for the period from 2000 to 2010. Reference is generally to violation of the food legislation standards and in some cases the biota EQS according to Directive 2008/105/EC. Trends are noted when these are apparent.

Even if the data are not directly comparable, they still give a good overview of the contamination situation in the catchment area of the Rhine.

5.1 Dioxins, furans, DL-PCBs

Overall, significant fluctuations in the content of dioxins and PCBs were found in all the species of fish studied. These fluctuations are due, on the one hand, to the differing contamination situation in the particular water body and the sampling location and, on the other, to the nature and composition of the samples.

Reliable values for the sum TEQ for dioxins, furans, and dioxin-like PCBs are provided in Appendix 5. Unless otherwise indicated, raw data are listed without the measurement uncertainty being taken into account. Violations of the limits under food legislation are consequently not indicated here.

The values range from less than 1 pg/g FW in the case of individual chub, brown trout, roach, pike, pike-perch, perch and wels catfish to more than 70 pg/g FW in eel. The example of the asp (lowest value: 0.91 pg/g FW in an example from the Moselle; highest value: 73.32 pg/g FW in an example from the Middle Rhine) shows that the contamination is not species-specific but depends, for one thing, on the pollution situation of the water body concerned at the sampling site and, for another, on the age and fat content of the individual fish (see 1.2).

In the case of eel, a virtually blanket violation of the limit of 12 pg/g FW was determined along the Rhine and in many of its tributaries. An exception to this are eel from Lake Constance and from a former arm of the northern Upper Rhine that is connected only upstream and is affected by groundwater. Violations of the limits according to food legislation are normally due to DL-PCBs as a component of the total TEQ (see Figures 4, 6, 7, 8, 15).

The ICPR’s suspended matter measurement programme for the period 1991–2007 makes possible a meaningful trend analysis for a dioxin-like PCB congener (PCB 118); this indicates a decreasing contamination.

5.2 Indicator PCBs

The limits for indicator PCBs under German and Dutch law (0.3 mg/kg) are sporadically exceeded in the Rhine itself (Upper Rhine to Delta Rhine) and in the Moselle and Main, namely in older, fat-rich eel and bream, but not in other species of fish. Investigation of the yellow eel from the Delta Rhine makes possible a meaningful trend analysis for indicator PCBs (see Figure 21). Since the 1980s, there has been a significant decrease in contamination here, from values greater than 3 mg/kg FW to values below 0.5 mg/kg FW; the same applies to the Moselle and to a lesser extent to the Saar.
5.3 Hexachlorobenzene
In the High and Upper Rhine, 2008 was the first time that no violation of the maximum levels permissible under the (German) ordinance on maximum quantities of residue was determined for hexachlorobenzene (HCB) (0.05 mg/kg FW or 0.5 mg/kg fat). These levels are still sporadically exceeded in eel in the Main area and in the Middle Rhine. In the Delta Rhine, a major decrease since the 1970s in HCB contamination of yellow eel was apparent, from more than 0.1 mg/kg FW to values of about 0.01 mg/kg FW. In Lake IJsselmeer, the Environmental Quality Standard (EQS) for biota according to Directive 2008/105/EC was achieved, namely 0.01 mg/kg FW.

5.4 Perfluorinated tensides
Clearly raised quantities of PFOS were identified, particularly in fish taken from the Rhine (Delta Rhine, Lower Rhine, Upper Rhine, High Rhine) (3 µg/kg to more than 70 µg/kg, with occasional extreme values of up to 126 µg/kg FW; BfR orientation value: 30 µg/kg; EQS proposed value: 9.1 µg/kg FW). The trend analysis in the Netherlands shows an increase since the 1970s to values greater than 100 µg/kg FW in the mid-1990s, followed by a decrease to values of between 7 to 58 µg/kg FW. For other PFTs, the values in the whole of the Rhine area were generally below the detection limit.

5.5 Mercury
The maximum levels of mercury permissible under EU foodstuffs legislation (1 mg/kg FW for eel and 0.5 mg/kg FW for other fish species) were only sporadically exceeded; values were generally between 0.7 and 0.35 mg/kg. The decrease in the concentration of mercury in fish from the Rhine itself between Weil and the Delta Rhine that was observed in the 1980s and 1990s has not continued. The biota standard of 0.02 mg/kg FW for mercury according to Directive 2008/105/EC is exceeded comprehensively and systematically in all parts of the catchment area of the Rhine.

Table 10: Estimate of trend in contamination of fish from the Rhine

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</tbody>
</table>

* Contamination with dioxin-like PCBs has only been measured since 2000, whereas contamination with indicator PCBs has in some cases been measured considerably longer.
6. Conclusion

Despite the extensive data available, it is extremely difficult to make statistically reliable statements about contamination of fish from the Rhine. Patterns of distribution and trends could be identified at no more than regional level. A standardised procedure for sampling through to analysis could make possible assessment of the contamination of fish at the level of the whole of the Rhine itself or the whole of the catchment area of the Rhine.

The results presented here – which come primarily from studies concerned with food legislation – can also not automatically be transferred to ecosystem questions. Well-founded conclusions in that regard would require data from specific studies, for example on the effects of pollutants on fish at different life stages, on fertility/reproduction in water bodies, associations with fish diseases, etc. Scientific studies of that kind are not currently foreseen in the Rhine States.
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## Appendices

### Appendix 1: Institutions involved and contacts in the Rhine States

<table>
<thead>
<tr>
<th>Country</th>
<th>Authority</th>
<th>Location</th>
<th>Case worker</th>
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<td>0033-1-45 14 4088</td>
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<td>Landesbetrieb Hessisches Landeslabor (LHL)</td>
<td>Wiesbaden</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE Federal</td>
<td>Umweltbundesamt (UBA)</td>
<td>Dessau</td>
<td>Christa Schröter-Kerman</td>
<td><a href="mailto:christa.schroeter-kerman@uba.de">christa.schroeter-kerman@uba.de</a></td>
<td>0049-30-8903 1501</td>
<td></td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Ministère de l'Intérieur, Administration de la Gestion de l'Eau</td>
<td>Luxembourg</td>
<td>Max Lauff</td>
<td><a href="mailto:max.lauff@eau.etat.lu">max.lauff@eau.etat.lu</a></td>
<td>00352-26 0286-47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ministère de la Santé, Service de la Sécurité Alimentaire</td>
<td>Luxembourg</td>
<td>Patrick Hau</td>
<td><a href="mailto:patrick.hau@ms.etat.lu">patrick.hau@ms.etat.lu</a></td>
<td>00352-247-75620</td>
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<tr>
<td>Luxembourg, France, Germany</td>
<td>Internationale Kommissionen zum Schutz der Moselle und der Saar (IKSMS)</td>
<td>Trier</td>
<td>Daniel Assfeld</td>
<td><a href="mailto:daniel.assfeld@iksms-cipms.org">daniel.assfeld@iksms-cipms.org</a></td>
<td>0049-651-73147</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Rijkswaterstaat/waterdienst (RWS)</td>
<td>Lelystad</td>
<td>Charlotte Schmidt</td>
<td><a href="mailto:charlotte.schmidt@rws.nl">charlotte.schmidt@rws.nl</a></td>
<td>0031-6-10012151</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wageningen UR - IMARES</td>
<td>IJmuiden</td>
<td>M. Kotterman, S. Glorius</td>
<td><a href="mailto:info.imares@wur.nl">info.imares@wur.nl</a></td>
<td>0031-317-480900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RIKILT - Instituut voor Voedselveiligheid</td>
<td>Wageningen</td>
<td>./</td>
<td><a href="mailto:info.rikilt@wur.nl">info.rikilt@wur.nl</a></td>
<td>0031-317-480256</td>
<td></td>
</tr>
</tbody>
</table>
Appendices 2 to 5 can be found at the end of the report.

Appendix 2: Pollutants investigated in fish from the catchment area of the Rhine

Appendix 3: Fish species investigated for pollutants in the catchment area of the Rhine

Appendix 4: Standards, regulations, and recommendations according to which the studies of contamination of the fish fauna in the Rhine catchment area were carried out

Appendix 5: Contamination of fish from the Rhine and its tributaries with dioxins, furans, and dioxin-like PCBs: results

Appendix 6: Terms and concepts from food legislation and eco-toxicology for estimating risks arising from contamination

**Action levels**

In addition to the maximum levels utilised in the report, action levels have been defined for a number of contaminants. These are a means for the responsible authorities and companies to identify those cases in which it is appropriate to determine a source of contamination and to take measures to reduce or eliminate it.

**Target values**

The target values determined by the EU indicate what level of contamination must be achieved in foods for humans and animals to reduce the exposure of the majority of the population to the TWI value for dioxins and dioxin-like PCBs determined by the EU's Scientific Committee on Food.

**Tolerable intake levels**

Tolerable intake levels are an estimate of the quantity of a substance in the air, food, or drinking water that can be consumed throughout a person's life without appreciable risk to health. The unit determined by the WHO is pg TEQ/kg bodyweight (BW) per day (TDI = tolerable daily intake) or per week (TWI = tolerable weekly intake).

The WHO's TWI value for dioxins, furans, and dioxin-like PCBs (as a sum parameter) is 14 pg TEQ/kg BW. For PFTs, EFSA\(^{36}\) has determined a TDI of 0.15 µg/kg BW and for PFOA a TDI of 1.5 µg/kg BW.

Because the TWI/TDI is a limit for average lifelong contamination, assessment of exposure based on individual meals is not meaningful. When determining consumption recommendations – for example for river fish with a particular contamination – account must also be taken of the intake of contaminants via other foods and the rest of the environment (for example possible air contamination in housing space).

**Calculation examples (worst-case scenarios):**

- A consumer with a body weight of 60 kg should only consume a 200 g serving of eel with a PCDD/F-PCB-TEQ of 35.1 ng/kg (a level of contamination that has been measured in Germany/Hesse, for example) every 16.7 weeks, i.e. a

---

maximum of 3 times per year, so that – taking into account the intake of dioxins/DL-PCBs through the rest of his food – the TWI of 14 pg/kg BW is not exceeded.

- For a person weighing 65 kg, once-weekly consumption of 150 g of eel with a concentration of approx. 40 pg PCDD/F-PCB-TEQ/g (a concentration that has regularly been measured in eel from the Dutch section of the Rhine catchment area) will lead to an intake of $150 \times 40 = 6000$ pg TEQ, or 92 pg TEQ/kg BW/week. In addition, there is an average level of background contamination of approx. 6 pg TEQ/kg BW/week, meaning that the total contamination comes to 98 pg TEQ/kg BW/week, i.e. 7 times the TWI value.

- A person weighing 60 kg who consumed a serving of 200 g of fish contaminated with the highest level determined in Germany (Hesse) would use up his TDI for PFOS by 280% and his TDI for PFOA by less than 1%.

- If one assumes an average consumption quantity of freshwater fish of 14.98 g/day for an average consumer weighing 60 kg, the TDI for the most heavily contaminated samples in Hesse would be used up by 21% for PFOS and by less than 0.1% for PFOA. For heavy consumers eating an average of 36.79 g/day, the TDI use by the most heavily contaminated samples amounts to 50% for PFOS and approx. 0.1% for PFOA.

Because it is extremely difficult to estimate the risk of contaminants intake from various sources in individual cases, authorities often recommend entirely refraining from consuming highly contaminated fish species such as eel.

**Bio-accumulation factors in fish**

In order to determine species-specific bio-accumulation factors (BAF) for PFOS, the concentrations in the muscle tissue and in the water were determined for the species eel, orfe, brown trout, barbel, bream, chub, perch, pike, and roach at a minimum of 12 different catch locations for each species in North Rhine- Westphalia in 2006 to 2008. The bio-accumulation factor (BAF) is non-dimensional and represents the quotients from the concentration of PFOS in fish muscle tissue ($\mu$g/kg DM) and in water ($\mu$g/kg water).

The average species-nonspecific bio-accumulation factor for PFOS in fish muscle tissue derived from all the available data for all the catch locations and fish species considered is $\sim 905$ and varies species-specifically or due to other influences between 539 (for example in chub) and 2284 (for example in perch, see Table 11).
Table 11: Calculated average bio-accumulation factors for PFOS (in fish muscle tissue) for various species of fish

<table>
<thead>
<tr>
<th>Species of fish</th>
<th>Number of catch locations</th>
<th>Number of samples</th>
<th>Bio-accumulation factor (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perch</td>
<td>19</td>
<td>71</td>
<td>2284</td>
</tr>
<tr>
<td>Eel</td>
<td>19</td>
<td>65</td>
<td>1799</td>
</tr>
<tr>
<td>Bream</td>
<td>16</td>
<td>48</td>
<td>1731</td>
</tr>
<tr>
<td>Brown trout</td>
<td>43</td>
<td>200</td>
<td>862</td>
</tr>
<tr>
<td>Roach</td>
<td>15</td>
<td>58</td>
<td>812</td>
</tr>
<tr>
<td>Pike</td>
<td>13</td>
<td>27</td>
<td>797</td>
</tr>
<tr>
<td>Barbel</td>
<td>14</td>
<td>33</td>
<td>773</td>
</tr>
<tr>
<td>Orfe</td>
<td>12</td>
<td>31</td>
<td>616</td>
</tr>
<tr>
<td>Chub</td>
<td>46</td>
<td>152</td>
<td>539</td>
</tr>
</tbody>
</table>

The ranges of values found are also in line as regards their scale with the values given in the relevant literature. For the bluegill, for example, a PFOS factor of 2796 was determined.37 For rainbow trout, values between 690 (skeleton) and 3100 (blood) were calculated.38 These results were taken into account when the "Substances" expert group within the Working Group on Water Issues (LAWA) was working out a proposal for an Environmental Quality Standard for fish consumption (EQSbiota.Human).39 When converted to the water concentration EQS biota.Human, the value derived for PFOS (9 µg/kg in fish muscle tissue) on the basis of the TDI value (tolerable daily intake) is 0.002 – 0.020 µg/l.

Based on the available data, no reliable values for bio-accumulation (BAF values) in Rhine fish can be calculated because the PFOS concentration in the Rhine (water samples) is often below the detection limit (<0.01 mg/l) (see Table 12: 20–28% of the measured values for PFOS are below the detection limit). If one substitutes half the detection limit for these values, average BAF values of between 1050 and 1950 are derived for the measurement/catch locations in the North Rhine-Westphalia section of the Rhine. In the tributaries, the spread of BAF values is even greater. The values lie between 143 and 2923, on average, including the Rhine measurement locations (n=16), 1022.

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39 LAWA "Substances" expert group (2010): PFOS data sheet. Drawn up by the Luhnstedt Analytical Laboratory; http://www.laenderfinanzierungsprogrammem.de/cms/WaBoAb_prod/WaBoAb/Vorhaben/LAWA/Vorhaben_des_Ausschusses_Oberflaechengewaesser_und_Kuestengewaesser_(AO)/O_5.07/L28_db_PFOS_Datenblatt_UQN-Vorschlag_1003158708448628300909157.pdf
Table 12: PFOS measurements at measurement locations in the North Rhine-Westphalia section of the Rhine in the period from 2007 to 02/2011. Water samples; in µg/l

<table>
<thead>
<tr>
<th>Measurement location</th>
<th>River km</th>
<th>Number of samples</th>
<th>Proportion of values &lt;DL*</th>
<th>Min.</th>
<th>Max.</th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bad Honnef</td>
<td>640.0</td>
<td>54</td>
<td>25.9%</td>
<td>&lt;0.01</td>
<td>0.078</td>
<td>0.013</td>
<td>0.010</td>
</tr>
<tr>
<td>Bad Godesberg</td>
<td>647.8</td>
<td>18</td>
<td>27.8%</td>
<td>&lt;0.01</td>
<td>0.031</td>
<td>0.012</td>
<td>0.006</td>
</tr>
<tr>
<td>Dormagen-Stürzelberg</td>
<td>725.9</td>
<td>14</td>
<td>21.4%</td>
<td>&lt;0.01</td>
<td>0.052</td>
<td>0.014</td>
<td>0.011</td>
</tr>
<tr>
<td>Düsseldorf-Flehe</td>
<td>732.3</td>
<td>30</td>
<td>23.3%</td>
<td>&lt;0.01</td>
<td>0.032</td>
<td>0.012</td>
<td>0.006</td>
</tr>
<tr>
<td>Lobith</td>
<td>863.2</td>
<td>20</td>
<td>20.0%</td>
<td>&lt;0.01</td>
<td>0.018</td>
<td>0.012</td>
<td>0.004</td>
</tr>
<tr>
<td>Kleve-Bimmen</td>
<td>865.0</td>
<td>53</td>
<td>22.6%</td>
<td>&lt;0.01</td>
<td>0.029</td>
<td>0.012</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*DL: Detection limit (0.01 µg/l) to calculate the average: 0.005 µg/l for values <DL

Figure 26: Investigations of PFOS concentrations (water samples) at selected survey measurement locations in the Rhine catchment area in North Rhine-Westphalia. Comparison of contents in the Rhine (green) and in tributaries (blue). The averages (n ≥ 6) for each measurement location for the period from 2007 to 02/2011 are shown, with the standard deviation.
Table 13: PFOS measurements at selected survey measurement locations in the North Rhine-Westphalia section of the Rhine in the period from 2007 to 02/2011 and calculated average bio-accumulation factors (BAF). (Water samples; in µg/l)

<table>
<thead>
<tr>
<th>River and km</th>
<th>Measurement location</th>
<th>Number of samples</th>
<th>Min. of samples</th>
<th>Max. of samples</th>
<th>Average</th>
<th>Standard deviation</th>
<th>Average BAF (µg/kg)/ (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhine 640</td>
<td>Bad Honnef</td>
<td>66</td>
<td>0.005</td>
<td>0.078</td>
<td>0.014</td>
<td>0.012</td>
<td>1056.9</td>
</tr>
<tr>
<td>Rhine 732</td>
<td>Düsseldorf-Flehe</td>
<td>35</td>
<td>0.005</td>
<td>0.032</td>
<td>0.013</td>
<td>0.006</td>
<td>1321.0</td>
</tr>
<tr>
<td>Rhine 865</td>
<td>Kleve-Bimmen</td>
<td>66</td>
<td>0.005</td>
<td>0.029</td>
<td>0.012</td>
<td>0.005</td>
<td>1950.7</td>
</tr>
<tr>
<td>Agger</td>
<td>Troisdorf</td>
<td>6</td>
<td>0.005</td>
<td>0.011</td>
<td>0.007</td>
<td>0.003</td>
<td>916.1</td>
</tr>
<tr>
<td>Emscher</td>
<td>Emscher mouth</td>
<td>23</td>
<td>0.016</td>
<td>0.044</td>
<td>0.029</td>
<td>0.008</td>
<td>437.7</td>
</tr>
<tr>
<td>Erft</td>
<td>Neuss-Eppingerhoven</td>
<td>20</td>
<td>0.005</td>
<td>0.032</td>
<td>0.009</td>
<td>0.009</td>
<td>142.9</td>
</tr>
<tr>
<td>Lenne</td>
<td>Hagen-Hohenlimburg</td>
<td>28</td>
<td>0.005</td>
<td>0.1</td>
<td>0.039</td>
<td>0.028</td>
<td>1196.9</td>
</tr>
<tr>
<td>Lippe 3.7</td>
<td>Wesel</td>
<td>21</td>
<td>0.005</td>
<td>0.03</td>
<td>0.013</td>
<td>0.007</td>
<td>1536.1</td>
</tr>
<tr>
<td>Lippe 145</td>
<td>Lippborg</td>
<td>105</td>
<td>0.005</td>
<td>0.056</td>
<td>0.012</td>
<td>0.011</td>
<td>315.1</td>
</tr>
<tr>
<td>Möhne</td>
<td>before enters the Ruhr</td>
<td>23</td>
<td>0.005</td>
<td>0.049</td>
<td>0.017</td>
<td>0.011</td>
<td>1542.6</td>
</tr>
<tr>
<td>Ruhr 2.65</td>
<td>Duisburg</td>
<td>49</td>
<td>0.005</td>
<td>0.055</td>
<td>0.027</td>
<td>0.015</td>
<td>751.2</td>
</tr>
<tr>
<td>Ruhr 114</td>
<td>Fröndenberg*</td>
<td>77</td>
<td>0.005</td>
<td>0.08</td>
<td>0.017</td>
<td>0.013</td>
<td>2922.9</td>
</tr>
<tr>
<td>Sieg 8.7</td>
<td>Menden</td>
<td>20</td>
<td>0.005</td>
<td>0.025</td>
<td>0.008</td>
<td>0.006</td>
<td>964.1</td>
</tr>
<tr>
<td>Stever</td>
<td>Haltern, below wastewater treatment plant</td>
<td>10</td>
<td>0.005</td>
<td>0.066</td>
<td>0.019</td>
<td>0.022</td>
<td>307.5</td>
</tr>
<tr>
<td>Volme</td>
<td>before enters the Ruhr</td>
<td>31</td>
<td>0.005</td>
<td>0.14</td>
<td>0.017</td>
<td>0.027</td>
<td>491.3</td>
</tr>
<tr>
<td>Wupper</td>
<td>Opladen</td>
<td>23</td>
<td>0.005</td>
<td>0.034</td>
<td>0.019</td>
<td>0.007</td>
<td>494.5</td>
</tr>
</tbody>
</table>

*The PFT concentrations in the Ruhr at Fröndenberg have decreased; fish data from previous period.

The differences in BAF values for the different rivers/measurement locations (Table 13) may be determined, for example, by different species of fish (see Table 11).
**MTR and HC5 levels**

The **maximum tolerable risk** indicates the concentration of a substance at which 95% of the potentially present species in an ecosystem are protected. MTR values can be indicated as concentrations in water, soil, air, or organisms. The MTR values have never achieved official status.

The standard level derived from the MTR levels for protection of the ecosystem for the eel – converted on the basis of a “standard fish” with 10% dry matter or 5% fat – is 320 µg/kg for PCB 153 and 38 µg/kg for HCB. Because the quantity of PCB 153 is seen as an indicator for the whole group of substances, there are no MTR levels for the other PCB congeners. Levels for other substances are given in Table 14.

**Table 14: MTR levels for eel in µg/kg for a standard fish with 10% dry matter or 5% fat.**
Because the quantity of PCB 153 is seen as an indicator for the whole group of substances, there are no MTR levels for the other PCB congeners listed here.

<table>
<thead>
<tr>
<th>Substance</th>
<th>MTR level (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB153</td>
<td>320</td>
</tr>
<tr>
<td>QCB</td>
<td>160</td>
</tr>
<tr>
<td>HCB</td>
<td>38</td>
</tr>
<tr>
<td>α-HCH</td>
<td>1600</td>
</tr>
<tr>
<td>β-HCH</td>
<td>60</td>
</tr>
<tr>
<td>γ-HCH</td>
<td>370</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>120</td>
</tr>
<tr>
<td>p,p'-DDE</td>
<td>22</td>
</tr>
<tr>
<td>p,p'-DDD</td>
<td>35</td>
</tr>
<tr>
<td>p,p'-DDT</td>
<td>23</td>
</tr>
<tr>
<td>∑DDT</td>
<td>26</td>
</tr>
</tbody>
</table>

Another value that indicates damage to the ecosystem by pollutants is the **HC5 level**. This indicates the concentration of a pollutant in prey animals at which 5% of predators are no longer “protected”. The HC5 level is above the “no observed effect level concentration” (NOEC), i.e. the maximum pollutant concentration at which no damage to an organism can be observed.
### Appendix 7: Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW</td>
<td>Bodyweight</td>
</tr>
<tr>
<td>DEHP</td>
<td>Bis(2-ethylhexyl) phthalate</td>
</tr>
<tr>
<td>EQS</td>
<td>Environmental Quality Standard</td>
</tr>
<tr>
<td>FW</td>
<td>Fresh weight</td>
</tr>
<tr>
<td>HCB</td>
<td>Hexachlorobenzene (fungicide, seed treatment substance)</td>
</tr>
<tr>
<td>HCBD</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>HC₅ value</td>
<td>Concentration in prey animals at which 5% of predators are no longer &quot;protected&quot;</td>
</tr>
<tr>
<td>HCH</td>
<td>gamma- hexachlorocyclohexane (= lindane)</td>
</tr>
<tr>
<td>MTR value</td>
<td>maximum tolerable risk</td>
</tr>
<tr>
<td>NOEC</td>
<td>no observed effect level concentration</td>
</tr>
<tr>
<td>OCPs</td>
<td>(persistent) organochlorine pesticides, for example =&gt; HCH</td>
</tr>
<tr>
<td>PBDE</td>
<td>Polychlorinated diphenyl ethers (flame retardants)</td>
</tr>
<tr>
<td>PCB</td>
<td>Polychlorinated biphenyls</td>
</tr>
<tr>
<td>PCDD</td>
<td>Polychlorinated dibenzo-p-dioxins</td>
</tr>
<tr>
<td>PCDD/F</td>
<td>Polychlorinated dibenzo-p-dioxins and dibenzofurans</td>
</tr>
<tr>
<td>PCDF</td>
<td>Polychlorinated dibenzofurans</td>
</tr>
<tr>
<td>PFOA</td>
<td>perfluorooctanoic acid</td>
</tr>
<tr>
<td>PFOS</td>
<td>perfluorooctanesulphonate</td>
</tr>
<tr>
<td>QCB</td>
<td>Quintochlorobenzene = pentachlorobenzene (PeCB; intermediate product in the manufacture of disinfectants and plant protective agents)</td>
</tr>
<tr>
<td>TEQ</td>
<td>Toxicity equivalent quantity</td>
</tr>
<tr>
<td>TDI</td>
<td>tolerable daily intake,</td>
</tr>
<tr>
<td>TWI</td>
<td>tolerable weekly intake in pg WHO TEQ/kg BW</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
</tbody>
</table>
Appendix 8: Questionnaire regarding ongoing and completed studies of contamination of the fish fauna in the Rhine catchment area

The various sections of part 3 of this report were written on the basis of this questionnaire.

A. General information about the studies

1. **Authority** carrying out the study, contact (e-mail, phone, if not already known)

2. What **investigations** of contamination of fish have been carried out in the area for which you are responsible since 2000?

3. **List of sources** (published reports, Internet links to databases, consumption recommendations, etc.)

B. Objectives, materials, and methods of the particular investigation

1. What were the **objectives** of the investigation and what standards were applied?
   - EU Fish Consumption Regulation (No. 1881/2006 of 19 December 2006)
   - Biota standard according to Water Framework Directive
   - National consumer protection standards
   - Ecotoxicological “standards”

2. What **substances** (or congeners) were measured and in what units, and in what form are the results presented? Is reference made to fresh weight or to fat?
   - DL-PCBs, in particular indicator indicator-PCBs, as far as possible PCB 153
   - Dioxins
   - Sum of dioxins and dioxin-like PCBs (for better comparability, an indication in WHO-PCDD/F-PCB-TEQ upper limit### in pg TEQ/g is preferable)
   - Furans
   - HCB
   - Mercury
   - PFTs

3. At what **measurement locations** were the investigations carried out? (If possible exact location, with Rhine km indication)

4. Which **fish species** were studied? What length categories (cm) were applied? What were the criteria for selecting these species?

5. **How many fish** were sampled? Were composite or single samples utilised? Were averages calculated? Did the sample involve fillet, other parts of the fish, or the whole fish?

C. Results of investigations, assessments

1. If investigations have already been carried out in the past: **is a trend** in contamination apparent?
2. Are **standards exceeded**? If so, which standards and to what extent? Was a conversion to **WHO TEQ** carried out for the substances for which these values are available?

3. Did the investigations lead to **prohibitions on consumption or marketing**? If so, where were they published? (Internet links etc.)
   Please state briefly the limits/weekly intake amounts (preferably: TWI in g, for what bodyweight)

4. What **conclusions** have you drawn for future investigations?
## Anlage 2: Untersuchte Schadstoffe in Fischen im Einzugsgebiet des Rheins

Um eine einheitliche Darstellung der Untersuchungsergebnisse zu gewährleisten, wurden die Messergebnisse in die nachstehenden Tabellen und Diagramme transformiert. Die summierten Parameter sind als Summenparameter im Sinne der internationalen Standards zu interpretieren.
### Anlage 3: Auf Schadstoffe untersuchte Fischarten im Einzugsgebiet des Rheins

Die Abkürzungen für die Institutionen sind Anlage 1 zu entnehmen.

**Die gelbe Markierung** im Rheininzugsgebiet bezieht Speisefische.

**orangefarbene Markierung:** von zahlreichen Staaten beprobte Fischart

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<th>Rheinländern</th>
<th>Frankreich</th>
<th>Deutschland</th>
<th>Mosel-Saar-Gebiet</th>
<th>Luxemburg</th>
<th>Niederlande</th>
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</table>

**DE-BY: Mischproben nur bei Fischgewicht < ca. 200 g. Weitere Fischarten: diverse Cypriniden.**

**DE-HE: Bei sehr kleinen Fischen wurden Kopf, Flossen und / oder Haut mit homogenisiert.**

**Kategorien nach durchschnittlichem Fettgehalt: Magerfische: ≤ 1% Fett, Mittelfette Fische: 1 bis 10% Fett, Fettfische: > 10% Fett.**

Prozentuale Angabe, sofern Wert bekannt.

---

* Die gelbe Markierung für die Institutionen sind Anlage 1 zu entnehmen.

**Die orangefarbene Markierung** im Rheininzugsgebiet bezieht Speisefische.

---
### Anlage 4: Normen, Verordnungen und Empfehlungen

durchgeführt wurden

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<th>Deutschland</th>
<th>Mosel-Saar-Gebiet</th>
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*Die Abkürzungen für die Institutionen sind Anlage 1 zu entnehmen.

**Im Jahr 2000, als eine der im Bericht zitierten Untersuchungen in Luxemburg durchgeführt wurden, existierten noch keine WHO- oder EU-Normen.**

### Geltungs-bereich

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<td>Dutch Maximum Residue Limits, <a href="http://www2.rijk.nl/vws/index.html">http://www2.rijk.nl/vws/index.html</a></td>
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**Anmerkung:** Im Jahr 2000, als eine der im Bericht zitierten Untersuchungen in Luxemburg durchgeführt wurden, existierten noch keine WHO- oder EU-Normen.
### Rheinabschnitt

<table>
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<tr>
<th>Lage der Messstelle</th>
<th>Rhein-km</th>
<th>Nation</th>
<th>Land, Kanton, Départ.</th>
<th>Institution</th>
<th>Jahr</th>
<th>Fischart</th>
<th>Wert min</th>
<th>Wert max</th>
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| **VORDER- und HINTERREIN**
| **Reichenau – Bodensee**
| Vorderrein bei Valendas | 26.10.2011 | VR | CH | GR | BAFU | 2004 | Bachforelle | 0,40 |
| Hinterrein bei Rothenbrunnen | | HR | CH | GR | BAFU | 2004 | Bachforelle | 1,00 |
| **ALPENRHEIN**
| | Haldensee | ARL | CH | GR | BAFU | 2004 | Bachforelle | 1,10 |

| **BODENSEE**
| |  |  |  |  |  |  |  |  |
| **BODENSEE – Basel**
|  |  |  |  |  |  |  |  |  |
| **OBERRHEIN**
| (km 0-83)
| |  |  |  |  |  |  |  |  |
| **Bodensee**
|  |  |  |  |  |  |  |  |  |
| **Augst, Fischpass**
|  |  |  |  |  |  |  |  |  |
| **OBERRHEIN**
| (km 170-529)
| |  |  |  |  |  |  |  |  |
| **Basel –ingen**
|  |  |  |  |  |  |  |  |  |

### Tabelle der Kontamination von Fischen im Rhein und seinen Nebenflüssen mit Dioxinen, Furanen und dioxinähnlichen PCB: Ergebnisse

Stand: 26.10.2011

<table>
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<tr>
<th>WHO-TEQ-Werte ohne Berücksichtigung der Messunsicherheit; vgl. Kap. 2.2 im Bericht</th>
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</table>

Die hier aufgeführten Werte können von den Werten, aufgrund derer über Verzehrsverbote entschieden wurde, erheblich abweichen.

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| **OBERRHEIN**
| (km 170-529)
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### WHO-PCDD/F + dl-PCB TEQ (ng / kg = pg / g FG)

VORDER- und HINTERREIN

HOCHRHEIN

OBERRHEIN

Anlage 5: Kontamination von Fischen im Rhein und seinen Nebenflüssen mit Dioxinen, Furanen und dioxinähnlichen PCB: Ergebnisse

WHO-PCDD/F + dl-PCB TEQ (ng / kg = pg / g FG)
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