Waters in Germany: Status and assessment

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1 Introduction

Our waters are used in a variety of ways, some of which entail man-made (anthropogenic) substance discharges. They influence the chemical quality of our waters, may harm the aquatic biotic communities, and may also impair uses such as drinking water abstraction. Hydraulic engineering measures aimed at flood prevention and the development of rivers to enable navigation and power generation have had a substantial impact on the nature and course of surface waters, which in turn has affected their ecological quality.

Surface waters and groundwater in Germany are analysed at regular intervals. Within the context of national and international monitoring programmes, the Laender collect data on the biological and chemical status of surface waters, as well as on their hydro morphology. For groundwater, they monitor quantity and quality with groundwater quality often being impaired by nitrate and pesticides. Balances of substance discharges into groundwater and surface waters from point sources are based on the results of regular discharger monitoring. Together with balance models, they provide information on the origins of problem substances, and facilitate the formulation of measures to reduce them. The assessment of pressures is based on uniform, legally binding procedures and environmental quality standards (EQS).

In 2000, the EU Water Framework Directive (WFD) was the first ecologically driven directive dedicated to water protection, calling for the extensive involvement of the general public. The Directive demands a good ecological and chemical status of surface waters, a good chemical and quantitative status of groundwater, and a good ecological potential of heavily modified or artificial water bodies (Directive 2000/60/EC). The Member States have been tasked with achieving these objectives. Environmental quality standards for chemical parameters and guidelines for biological status classes have been introduced to facilitate monitoring of these objectives in surface waters, while groundwater quantity and chemical status are assessed using a range of criteria.

Ordinances governing surface waters and groundwater translate the WFD's requirements on the assessment of water bodies into national regulations. The Ordinance on Surface Waters requires the type-specific measurement of rivers, lakes, transitional and coastal waters, and an integrative assessment of the ecological status. The responsible Laender have designed monitoring programmes to ascertain the biological colonisation of water bodies. The comparison with the biotic communities specific for the respective area and occurring in an undisturbed environment enables the authorities to assess the ecological quality of water bodies and the probable causes of any pollution. The Ordinance on Surface Waters (Oberflächengewässerverordnung, OGewV) requires sufficiently reliable and accurate results for biological and chemical analyses, and quality assurance of data is therefore an important consideration.

The Ordinance on the Protection of Groundwater sets threshold values for assessing the chemical status and other criteria for classifying the status as "good" or "poor", based on representative surveys of each water body. If pollutants tend to rise, the competent authorities are required to take action to reverse this trend if they reach 75 % of the limit values.

The EU Marine Strategy Framework Directive (MSFD) demands the comprehensive assessment and protection of all the key elements in marine ecosystems with regard to their mutual interactions and potential cumulative effects of the EU Member States (Directive 2008/56/EC). The Directive incorporates the assessment approaches of the WFD and the Habitats Directive. The monitoring and assessment of marine ecosystems and their pressures relies on cooperation between the Parties to the regional Conventions on the Protection of the North-East Atlantic (Oslo-Paris Convention, OSPAR) and the Baltic Sea (Helsinki Convention, HELCOM). New monitoring and assessment techniques for MSFD aspects such as marine litter and noise have been developed or are currently under development.

This report outlines the principal aspects of the status of surface waters and groundwater, with a particular emphasis on the current pollution situation. It also analyses the development of water quality of flowing Waters (rivers, streams), large lakes, transitional (estuarine), coastal and marine waters of the North and Baltic Seas, which are assessed based on data provided by both the Federal Government and the Laender, together with the results of scientific publications, research projects and the German Environment Agency's own work. By presenting facts and figures, this Report sets out to provide information about the status of Germany's water bodies and to highlight existing problems in the field of water protection.

Quelle: Dr. Andreas Hoffmann

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2 Basis for the assessment of groundwater and surface waters

2.1 The European assessment systems

The EU Water Framework Directive (WFD) and the EU Marine Strategy Framework Directive (MSFD) call on Member States not to deteriorate the status of water bodies ("deterioration ban") and to improve it where good status is not reached. The status of waters is integratively assessed using a range of assessment criteria such as biology, chemistry, water quantity and hydromorphology (WFD), together with noise and litter (MSFD).

"Water bodies" were introduced by the WFD as objects of assessment and management. Water bodies are certain sections or parts of waters underlying uniform pressures and structures, and belonging to a specific "category" (groundwater, river, lake, transitional or coastal water) and "type". The ecological status of surface waters (rivers, lakes, transitional and coastal waters) is characterised as status "close to natural conditions". The reference criteria for such status close to natural conditions and hence for the assessment are water type-specific reference conditions for the existence and abundance of flora and fauna, physico-chemical conditions (such as nutrients, oxygen, temperature and pH value), and hydro morphology. Ecological status is defined according to the degree of deviation from these reference conditions. Additionally, national environmental quality standards (EQS) apply to (specific) pollutants with regional relevance.

The WFD defines the chemical status of surface waters in terms of compliance with valid European-wide environmental quality standards for pollutants. Trend monitoring of biota, suspended solids and sediment is required in order to be able to assess the long-term impacts of pollutants.

Groundwater bodies are assessed according to the criteria "quantity" and "quality". The quantitative status is considered good, provided the long-term average annual abstraction of groundwater does not exceed the groundwater available. Chemical status is assessed according to compliance with European-wide threshold values for nitrate and pesticides, and national threshold values for eight further pollutants.

The MSFD lists eleven descriptors of environmental quality for defining the ecological status of marine regions. Some of the descriptors refer to pressures (populations of commercially exploited fish and shellfish, eutrophication (=oversupply of nutrients), existence of non-indigenous species, permanent alteration of hydrographical conditions, contaminants in the ecosystem and in in seafood, marine litter, the introduction of energy (e.g. noise)), while others refer to the status of the ecosystem (biodiversity, food webs, sea floor integrity).

Below, aspects of water assessment which are equally applicable to groundwater and surface waters, including coastal and marine waters, are explained. These include basic principles for the specification of threshold values for groundwater and environmental quality standards in surface waters, together with requirements governing the confidence and precision of measurement results. The following aspects are covered in greater detail in the chapters cited:

- Quality standards and threshold values in groundwater and the assessment of quantitative status in chapter 3.1
- Environmental quality standards in surface waters in chapter 4
- The assessment of biological, hydromorphological and physico-chemical quality elements in rivers and lakes in chapters 5.1 and 6.1, and
- The assessment of transitional and coastal waters and the oceans in chapter 7.1.

2.2 Criteria for pollutants in water protection

Households, industry, trade, transport and agriculture discharge a wide range of chemicals into waters. As analytical techniques become ever more advanced, an increasing number of substances are being found in ever smaller concentrations in waters. The WFD requires a check of their relevance to both environmental protection and health protection, and the specification of environmental quality standards where necessary. It groups substances into those with EU-wide importance and those with local importance for groundwater and surface waters.

For surface waters, these environmental quality standards are defined in the Ordinance for the Protection of Surface Waters (Grundwasserverordnung, GrwV; see chapter 4):

- With respect to the chemical status, Directive 2008/105/EC defines environmental quality standards for 45 priority and 5 other substances/substance groups, together with nitrate, for which an action value has been defined under the Nitrates Directive (Council Directive 91/676/EC).
- The ecological status is assessed according to other environmental quality standards for specific pollutants discharged into river basins in significant quantities.

For groundwater, the threshold values are regulated by the Groundwater Ordinance (see chapter 3.1):

- The chemical status of groundwater is defined by uniform European quality standards for nitrate (50 mg/l) and pesticides (0.1 µg/l per substance).
- Additionally, the Member States must specify threshold values for those parameters/substances which have led to an "at risk" classification following an inventory of pressures, but a set of minimum European-wide parameters has been defined as well.

2.3 Reliability of analytical results

In order to ensure the reliability of analytical results within the context of monitoring, the Directive laying down technical specifications for chemical analysis and monitoring of water status (Commission Directive 2009/90/EC) and Annex 9 to the Ordinance on the Protection of Surface Waters set out minimum performance criteria for the analytical methods to be applied. Thereto, only methods with a maximum measurement uncertainty of 50 %, and limits of quantification equal to or less than 30 % of the relevant environmental quality standard should be used for the monitoring of waters. Furthermore, all laboratories involved in the monitoring of waters must have established a quality management system based on DIN EN ISO/IEC 17025 and have participated in suitable proficiency testing programmes. Although accreditation is not compulsory, many laboratories regularly make use thereof to obtain from an independent body the confirmation of their competency to perform certain analyses.

2.4 Quality assurance

The accuracy and comparability of the data collected (cf. also chapter 7.1.4) is a key requirement for both the characterisation of the status of waters and the assessment of anthropogenic influences and the measures to be taken. The current preference is therefore to use national and international standard methods for chemical, physical and biological monitoring, as summarised in the "German Standard Methods for the Examination of Water, Wastewater and Sludge".

The accreditation and/or notification of laboratories is one way of ensuring or improving the quality of analytical data. Analytical laboratories are accredited according to the standard DIN EN ISO/IEC 17025 "General requirements for the competence of testing and calibration laboratories", which entails the formal recognition of a laboratory's competence by an authorised body to carry out certain analyses. Notification entails the formal recognition and publication of laboratories authorised to perform certain analytical tasks in areas regulated by law (e.g. for drinking water and wastewater analyses) by the competent Land authority. Notification generally requires accreditation, and where necessary, an assessment of competency by the competent authority.


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3 Groundwater

3.1 Basis for assessment

Groundwater resources in many areas are under threat. This is often the case if inputs of substances exceed the buffering and filtering capacity of the soil layers above them. Groundwater contamination often manifests itself as long-term damage which is not immediately apparent. Remediation, if at all possible, will be expensive, time-consuming and require extensive technical resources. For this reason, preventive, nationwide groundwater protection is particularly vital. Systematic, regular monitoring of groundwater quality is a crucial element of groundwater protection. If measures have been introduced to protect or restore groundwater resources, the monitoring results can provide major insights into the efficacy and effectiveness of such measures. A number of substances have been analysed and evaluated with regard to their risk potential and probability of discharge over various periods. The EU Water Framework Directive (WFD) calls for the assessment of groundwater status at the level of groundwater bodies, defined as “a distinct volume of groundwater within an aquifer or aquifers”.

3.1.1 Quantitative status

The WFD calls for a good quantitative status of all bodies of groundwater (Annex V, no. 2.1 of Directive 2000/60/EC). The parameter for assessing the quantitative status of groundwater is the groundwater level. The quantitative status of groundwater is considered good provided the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. In very simplified terms, this means that the groundwater level must not be subject to any anthropogenic alterations that would result in

- Failure to achieve the environmental objectives for associated surface waters
- Any significant diminution in the quality of such waters
- Any significant damage to terrestrial ecosystems which depend directly on the groundwater body
- Alterations to flow direction causing salt water or other harmful intrusions.

In practice, however, assessing the quantitative status with an adequate degree of reliability entails more than just considering the groundwater level or its development. As such, it is necessary to evaluate the water regime in the individual body of groundwater or sections thereof.

3.1.2 Chemical status

The EU Groundwater Directive (Directive 2006/118/EC), a daughter directive to the WFD, sets out quality requirements (so-called groundwater quality standards and threshold values) for a number of substances. If a body of groundwater adheres to these values, it is considered to have a good status. If it exceeds them, the nature and extent of exceedance must be investigated, and if necessary, the body of groundwater designated as having failed to achieve a good status. In such cases, Member States are obligated to carry out suitable programmes of measures in order to restore it to a good status, i.e. to reduce pressures until the groundwater quality standards and threshold values are met. The EC Groundwater Directive sets out European-wide groundwater quality standards for the following substances and substance groups:

- Nitrate – 50 mg/l and
- Pesticides (= plant protection agents and biocides) – [limit for individual substance: 0.1 µg/l, summative limit: 0.5 µg/l].

These values were also transposed into the German Groundwater Ordinance (GrwV). Additional threshold values must be set at national level for substances which could cause a body of groundwater to fall short of a good status. Threshold values for 8 further substances and substance groups are currently defined in Annex 2 to the Groundwater Ordinance (see Table 1).

Table 1

Groundwater quality standards and threshold values for the classification of chemical groundwater status

Name of substance	CAS no.	Threshold value	Derivation criterion
Nitrate		50 mg/l	Groundwater quality standard as per Directive 2006/118/EC
Active ingredients in pesticides and biocide products including relevant metabolites, degradation and reaction products		0.1 µg/l each; 0.5 µg/l in total	Groundwater quality standard as per Directive 2006/118/EC
Arsenic	7440-38-2	10 µg/l	Drinking water – Limit for chemical parameters
Cadmium	7440-43-9	0.5 µg/l	Eco-toxicologically derived: PNEC resp. background value
Lead	7439-92-1	10 µg/l	Drinking water – Limit for chemical parameters
Mercury	7439-97-6	0.2 µg/l	Eco-toxicologically derived: PNEC resp. background value
Ammonium	7664-41-7	0.5 mg/l	Drinking water – Limit for indicator parameters
Chloride	168876-00-6	250 mg/l	Drinking water – Limit for indicator parameters
Sulphate	14808-79-8	250 mg/l	Drinking water – Limit for indicator parameters
Sum total of tri- and tetrachloroethylene	79-01-6; 127-18-4	10 µg/l	Drinking water – Limit for chemical parameters

PNEC = Predicted No Effect Concentration

Source: Annex 2 to the Groundwater Ordinance

3.1.3 Monitoring networks for reporting

The WFD obligates Member States to set up networks for monitoring the chemical and quantitative status of groundwater. Chemical status is ascertained at operational monitoring sites and surveillance monitoring sites. Surveillance monitoring sites have been established primarily in unpolluted bodies of groundwater, whereas operational monitoring sites have been established in bodies of groundwater with poor status. In Germany, the Laender are responsible for the creation and operation of monitoring networks. In total, the Laender have 4,892 surveillance monitoring sites, 2,273 operational monitoring sites and just under 6,000 monitoring sites for monitoring quantitative status.

Furthermore, until early 2015 there were two cross-Laender monitoring networks which drew data from existing monitoring sites in the Laender networks. Both networks supplied the data basis for the Federal Republic of Germany's reports to the European Union (EU) and the European Environment Agency (EEA). The EEA monitoring network comprises some 800 monitoring sites, and supplies data for annual reports to the EEA on the status of groundwater in Germany. By contrast, the data from the EU nitrate monitoring network provided the basis for the Federal Republic of Germany's Nitrate Report on implementation of the EU Nitrate Directive (Council Directive 91/676/EEC), which must be submitted to the EU Commission every four years.

Following a resolution by the German Working Group on water issues of the Laender and the Federal Government (LAWA), the EU nitrate monitoring network has been revised, combined with the EEA monitoring network, and extended to around 1,200 monitoring sites.

The monitoring sites in the new monitoring network were selected according to the following criteria:

- Monitoring sites should be located in the groundwater aquifer, as close as possible to the surface (top groundwater aquifer, open groundwater with no barrier layer), so that nitrate inputs from land use are included in the groundwater covered by the monitoring sites.
- The chosen monitoring sites should representatively reflect the distribution of land use (human settlements, forest, grassland, arable land and special crops) in the Laender and hence in Germany as a whole. The number of monitoring sites in individual Laender is calculated according to land size.
- Monitoring sites should still be representative of the regional distribution of nitrate loads in groundwater.
- Historical measurement data from the chosen monitoring sites should be made available dating back to at least 2008, to facilitate comparisons with the current reporting period.
- As far as possible, the old EEA and EU nitrate monitoring sites used as a basis for the first five nitrate reports should be transferred into the new monitoring network.

These guidelines and the available monitoring sites led to around 1,200 monitoring sites and a monitoring network density of around 3.5 monitoring sites per 1,000 km^2 in Germany. The EEA monitoring network therefore provides a representative overview of the pressures on groundwater in Germany spanning all land uses.

The EC Nitrates Directive calls for nitrate levels in water bodies to be correlated with agricultural use (Article 5 of Council Directive 91/676/EEC). As such, nitrate reporting under the EEA monitoring network only selects or scrutinizes in greater depth those monitoring sites whose catchment areas include groundwater monitoring sites dominated by

- Field
- Grassland
- Special crops.

The monitoring sites have been combined into an "agricultural monitoring subnetwork", also known as the "EU nitrate monitoring network". This new EU nitrate monitoring network comprises 697 monitoring sites, more than four times as many as the old network. It representatively outlines the influence of agricultural use on the properties of superficial groundwater in Germany. The data from this EEA monitoring network provides the basis for some of the assessments outlined below.

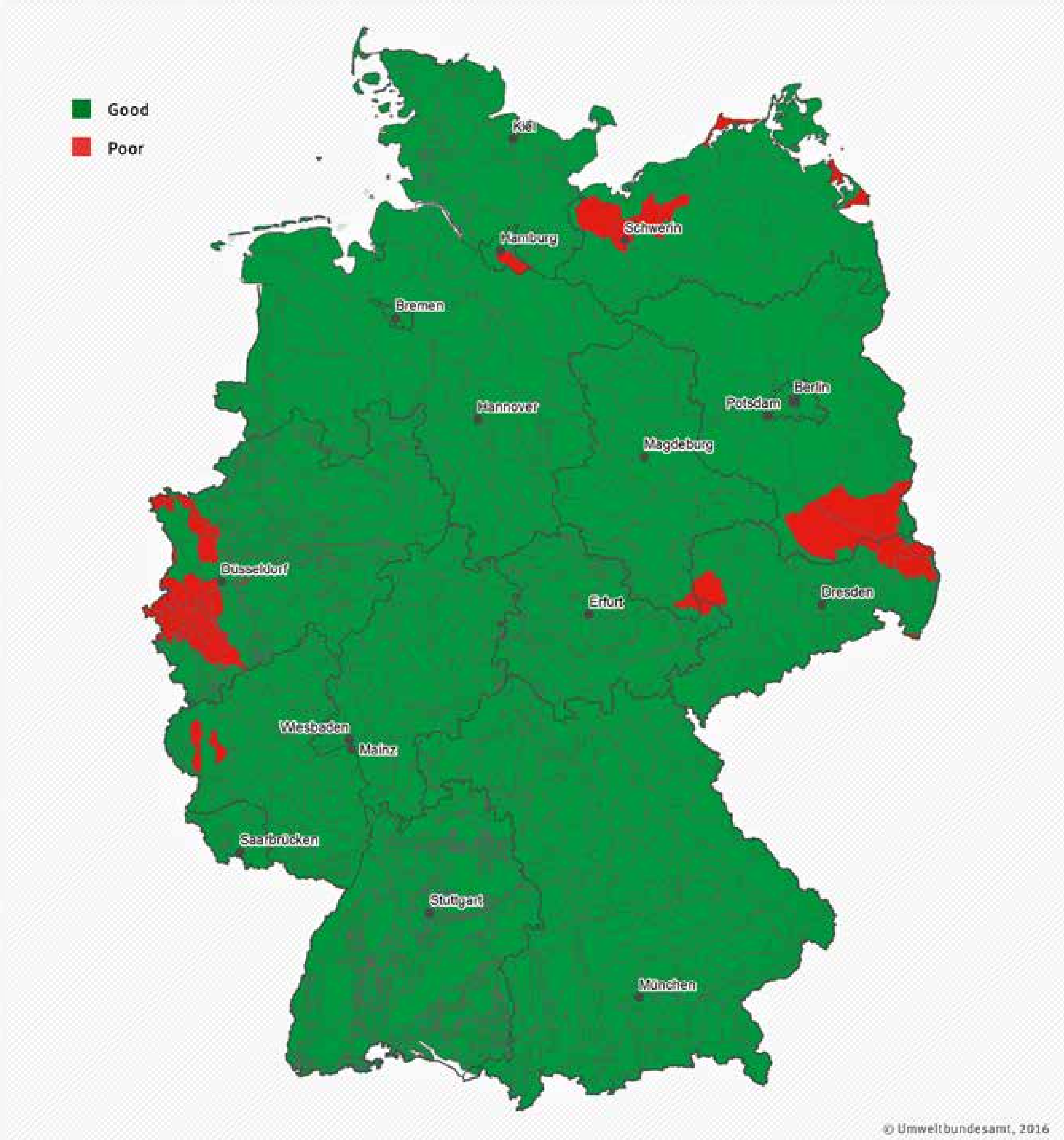
3.2 Status assessment

3.2.1 Quantitative status of groundwater bodies

Figure 1a shows the quantitative status of groundwater bodies in Germany. Overall, there are only a few groundwater bodies in Germany with quantitative problems. Out of a total of around 1,253 groundwater bodies, only 52 (4.2 %) failed to achieve a "good quantitative status" in 2016 (LAWA 2016b).

Figure 1a

Quantitative status of groundwater bodies in Germany

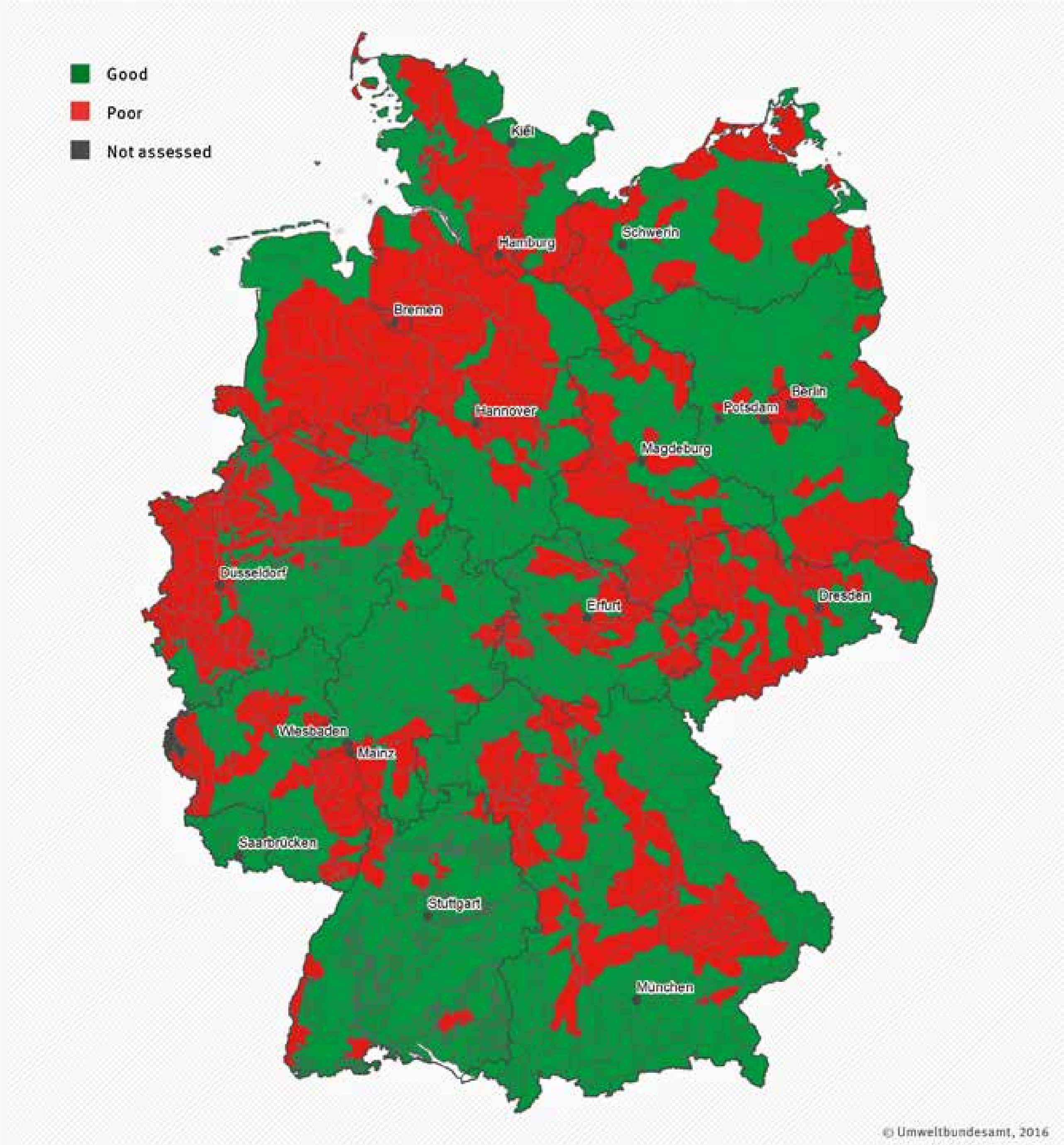


Source: Geobasis data: GeoBasis-DE/BKG 2015, professional data: LAWA 2016b, edited by: German Environment Agency, German Working Group on water issues of the Laender and the Federal Government (LAWA)

Quantitative problems can arise, for example, in conjunction with mining activities, particularly open-cast lignite mining. In these regions, the groundwater level has often been lowered substantially over several decades. Even after mining is discontinued, it will take many decades for the groundwater to return to its natural level. In regions where salt deposits are mined on a large scale, there is an increased occurrence of man-made salt intrusions, as a result of which the status of the affected groundwater body is classified as "poor". If the intrusion of saltwater is attributable to high levels of water abstraction, the groundwater body has a poor quantitative status. On the other hand, if the salt levels are caused e.g. by wastewater emissions from salt mining, the groundwater body will have a poor chemical status. The applicable assessment can only be determined on a case-by-case basis. Here too, it will probably take a long time for the groundwater body to attain a natural state and return to a "good status".

Figure 1b

Chemical status of groundwater bodies in Germany



Source: Geobasis data: GeoBasis-DE/BKG 2015, professional data: LAWA 2016b, edited by: German Environment Agency, German Working Group on water issues of the Laender and the Federal Government (LAWA)

3.2.2 Chemical status of groundwater

Valid European-wide quality standards for nitrate and pesticides, together with threshold values for relevant pollutants set by the Member States, are the benchmark for assessing the chemical status of groundwater (see chapter 3.1.2). A recent assessment of the chemical status of groundwater in Germany indicates that 34.8 % of all groundwater bodies have a poor chemical status (Figure 1b). This is primarily due to diffuse pollution with nitrate (27.1 % of groundwater bodies exceed the quality standard) and pesticides (2.8 % of groundwater bodies exceed the quality standard) from agriculture (LAWA 2016b).

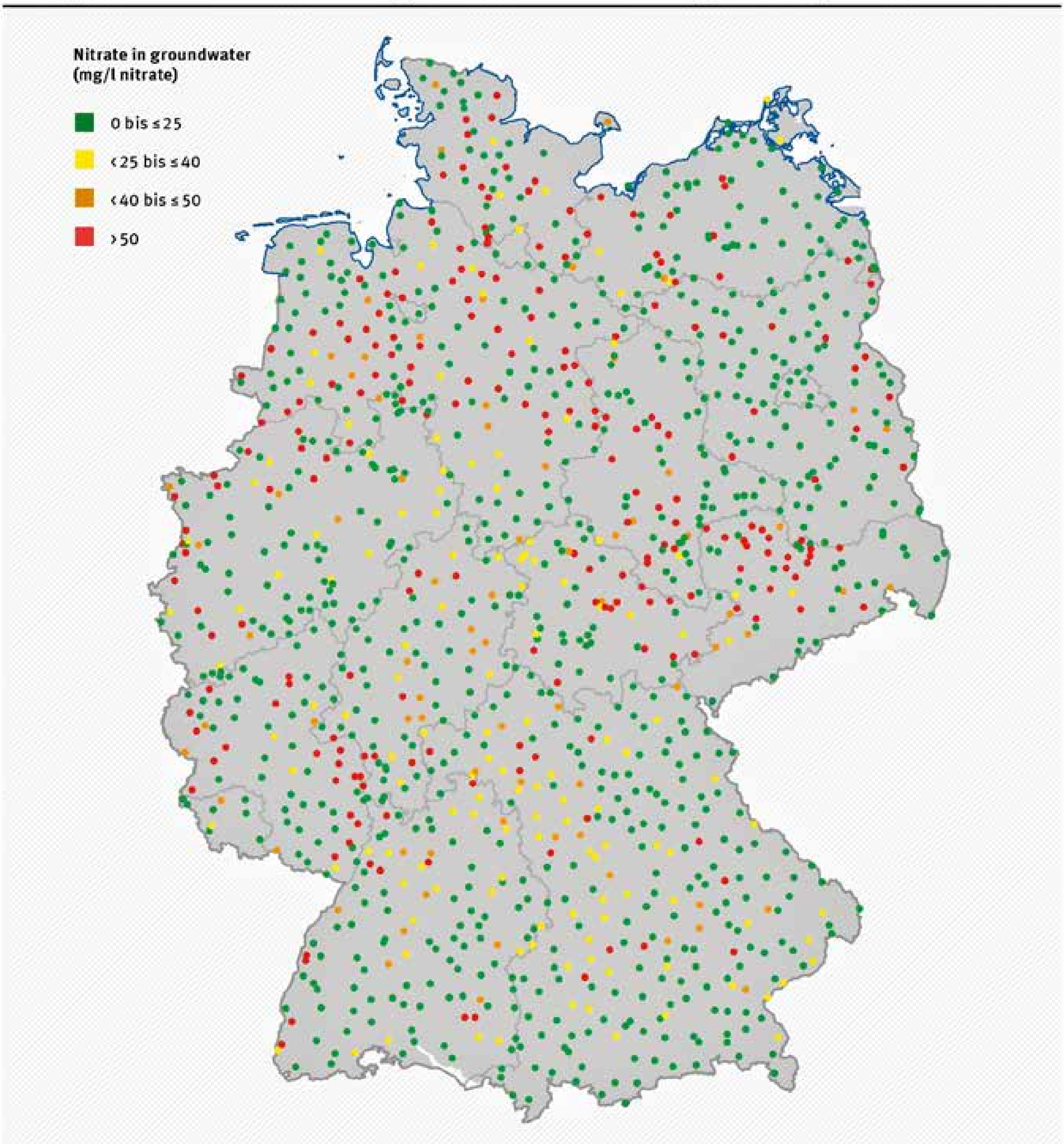
Nitrate in groundwater

Nitrogen compounds – generally nitrate – are the most common reason for poor status of groundwater in Germany and most European countries. Based on data from the EEA monitoring network, the following picture shows groundwater pollution in Germany (see Figure 2) for the period 2012–2014:

Monitoring data showing the nitrate concentrations in groundwater are available for 1,215 monitoring sites in the new EEA monitoring network for the period 2012–2014 (Figure 3). Around 64.5 % of all monitoring sites indicate nitrate concentrations of between 0 and 25 mg/l and are therefore not polluted at all, or only moderately. In 17.4 % of monitoring sites, the nitrate

Figure 2

Average nitrate levels at monitoring sites in the EEA monitoring network, 2012–2014



Source: Geobasis data: DLM1000, 2015, BKG, professional data: LAWA, edited by: German Environment Agency 2016 content is between 25 and 50 mg/l, meaning that they are significantly to heavily polluted with nitrate. The remaining 18.1 % of monitoring sites are so heavily polluted with nitrate that the water cannot be used for drinking water abstraction without further treatment, because it exceeds the limit of 50 mg/l set by the Drinking Water Ordinance, in some cases significantly.

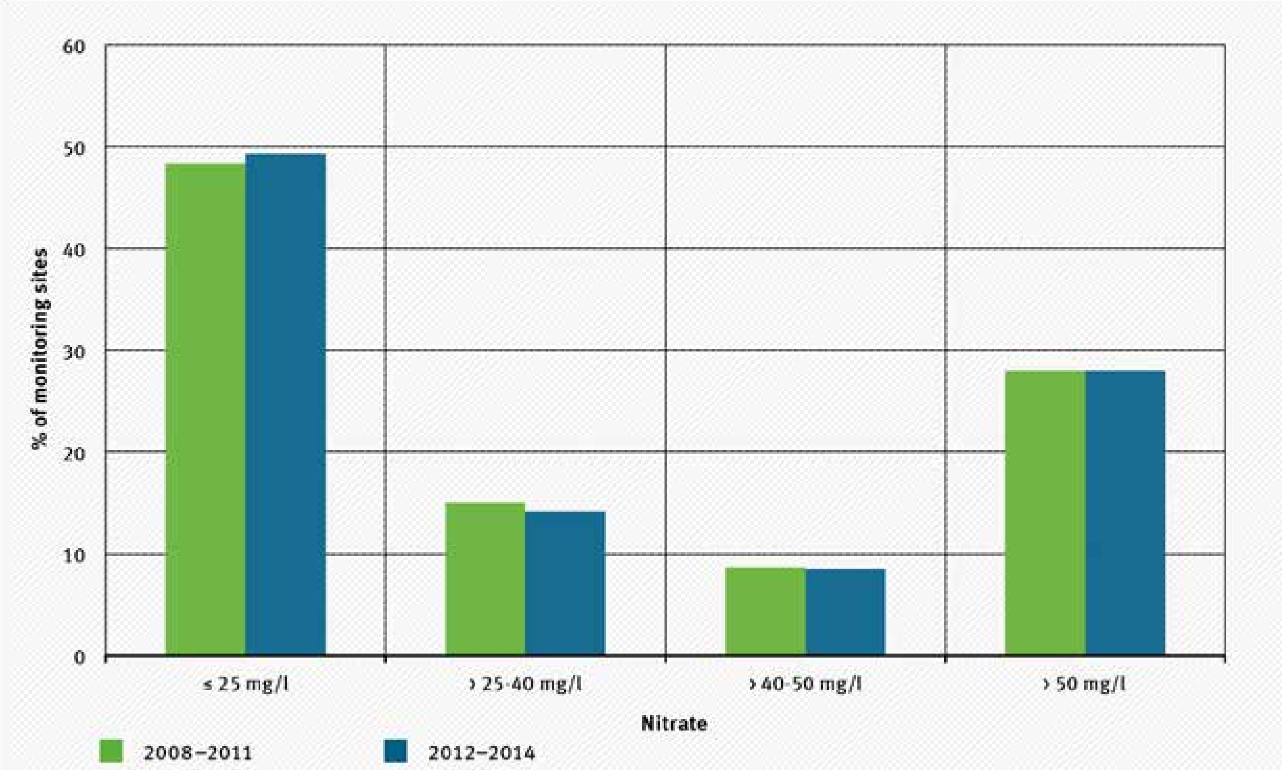
Clues to the principal reasons for nitrate inputs into groundwater are obtained by comparing the preferred land uses in the catchment area of a given measuring point with the nitrate content in groundwater. The lowest nitrate pollution level overall is found in the group of monitoring sites whose surrounding area is dominated by forest. If the surrounding area of the monitoring sites is dominated by grassland (meadows and fields), the number of points highly polluted with nitrate increases. If there is farmland or settlement areas in the vicinity, then the proportion of monitoring sites with nitrate concentrations in excess of 50 mg/l increases still further. Nitrogen inputs from agriculture are therefore the main reason for the groundwater pollution with nitrate.

In order to protect the groundwater in regions with intensive agricultural use, in 1991 the EU adopted Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (Nitrates Directive). The Nitrates Directive requires compliance with "best practices" in agriculture, and the implementation of advanced reduction measures within the context of action programmes. Member States must prove the effectiveness of the programmes of measures in the form of targeted groundwater measurements, and regularly submit reports to the Commission. Since 2016, the new EU nitrate monitoring network (see chapter 3.1.3) provides the database for Germany's reports.

Reporting under the Nitrates Directive shows how nitrate levels at the heavily polluted points of the EU nitrate monitoring network have changed over time (Figure 3). Following the redesign of the monitoring network, comparable data on the development of nitrate pollution is currently only available for the periods 2008–2011 to 2012–2014.

Figure 3

Frequency distribution of average nitrate levels for the periods 2008–2011 and 2012–2014 in the EU nitrate monitoring network



Source: German Environment Agency after BMUB and BMEL 2017

Overall, we can assert that measures implemented under the various action programmes in the periods 2008–2011 and 2012–2014 have not yet led to a significant reduction in the nitrate pollution of groundwater (Figure 4). Effects on groundwater nitrate concentrations may be significantly delayed, however, because the percolation time from the soil surface, through the water-unsaturated covering layers, into the groundwater can often take years or even decades. A comparison of the periods 2008–2011 and 2012–2014 (Figure 4) also shows a slight or sharp increase in nitrate concentrations at 27.7 % of all monitoring sites in the EU nitrate monitoring network. Over the same period, 33.4 % of monitoring sites indicate a slight to sharp decrease in nitrate concentrations. The proportions of monitoring sites with a sharp increase or sharp decrease in nitrate concentrations are very similar, at 15.9 % and 16.3 % respectively (BMUB and BMEL 2017).

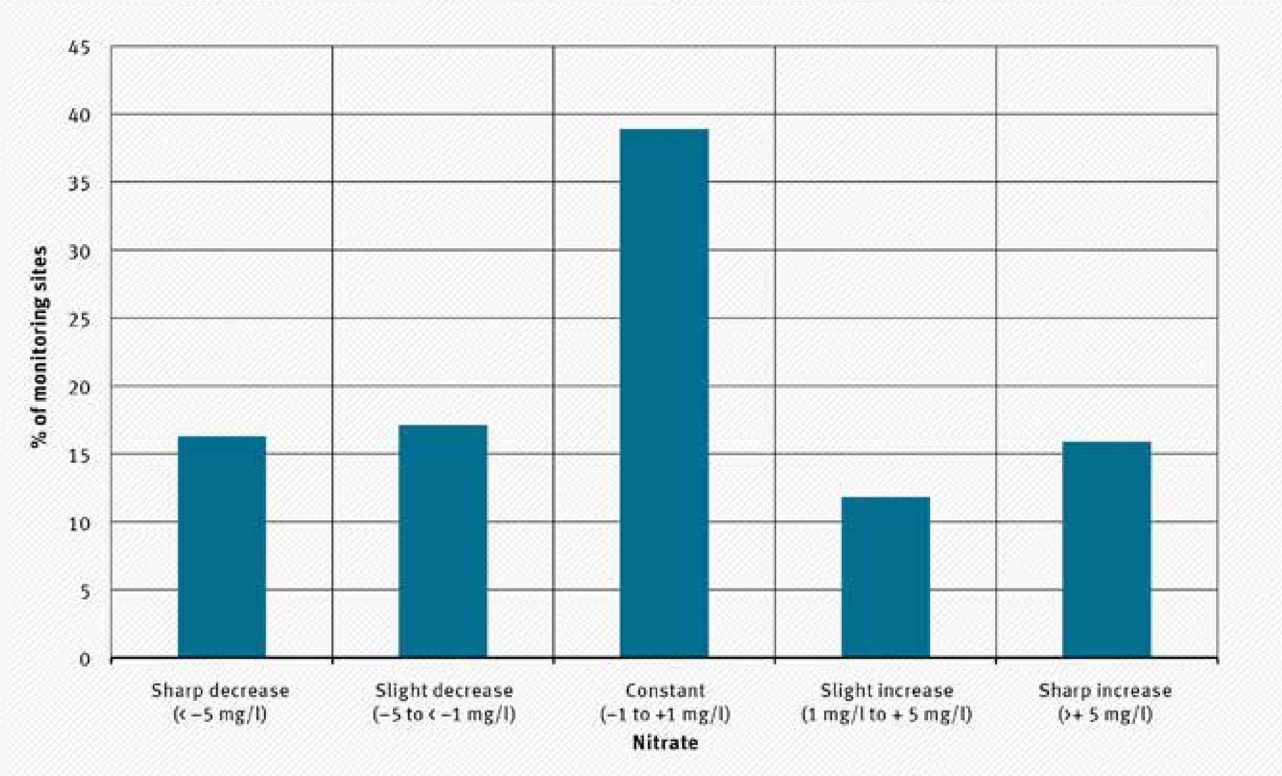
Pesticides

From time to time, the German Working Group on water issues of the Laender and the Federal Government (LAWA), in collaboration with the German Environment Agency (UBA), compiles a summarising report on the pollution of groundwater with pesticides. The 4th LAWA Pesticide Report was published in 2015, and provides an overview of groundwater pollution during the period 1990 to 2012. Throughout all five monitoring periods (1990–1995, 1996–2000, 2001–2005, 2006–2008 and 2009–2012), there was a significant reduction in the number of monitoring sites where the pesticide limit of 0.1 µg/l was exceeded (Figure 5). However, the decrease in groundwater pollution was found to be primarily attributable to decreasing discoveries of atrazine, desethylatrazine and several other active ingredients and metabolites whose use has been banned for years, or even decades (LAWA 2015a).

Between 2009 and 2012, 4.6 % of the 13,400 monitoring sites analysed still exceeded the limit of 0.1 µg/l in groundwater close to the surface. Groundwater pollution with pesticides has therefore remained virtually unchanged compared with the period 2006–2008.

Figure 4

Frequency distribution of changes in average nitrate levels between the periods 2012–2014 and 2008–2011 among EU nitrate monitoring sites (number of monitoring sites = 692)



Source: German Environment Agency after BMUB and BMEL 2017

For the first time, the 4th LAWA Pesticide Report systematically evaluated findings of so-called “non-relevant metabolites” for the whole of Germany. Under plant protection law, “non-relevant metabolites” (nrm) refer to the metabolites of active ingredients in pesticides which no longer have a pesticide effect and are comparatively safe in terms of their human- and eco-toxicological properties. For this reason, their licensing is subject to a value of between 0.75 and 10.0 µg/l for “non-relevant metabolites”, depending on toxicity (EU COM 2003), rather than the threshold value for active ingredients and relevant metabolites of 0.1 µg/l.

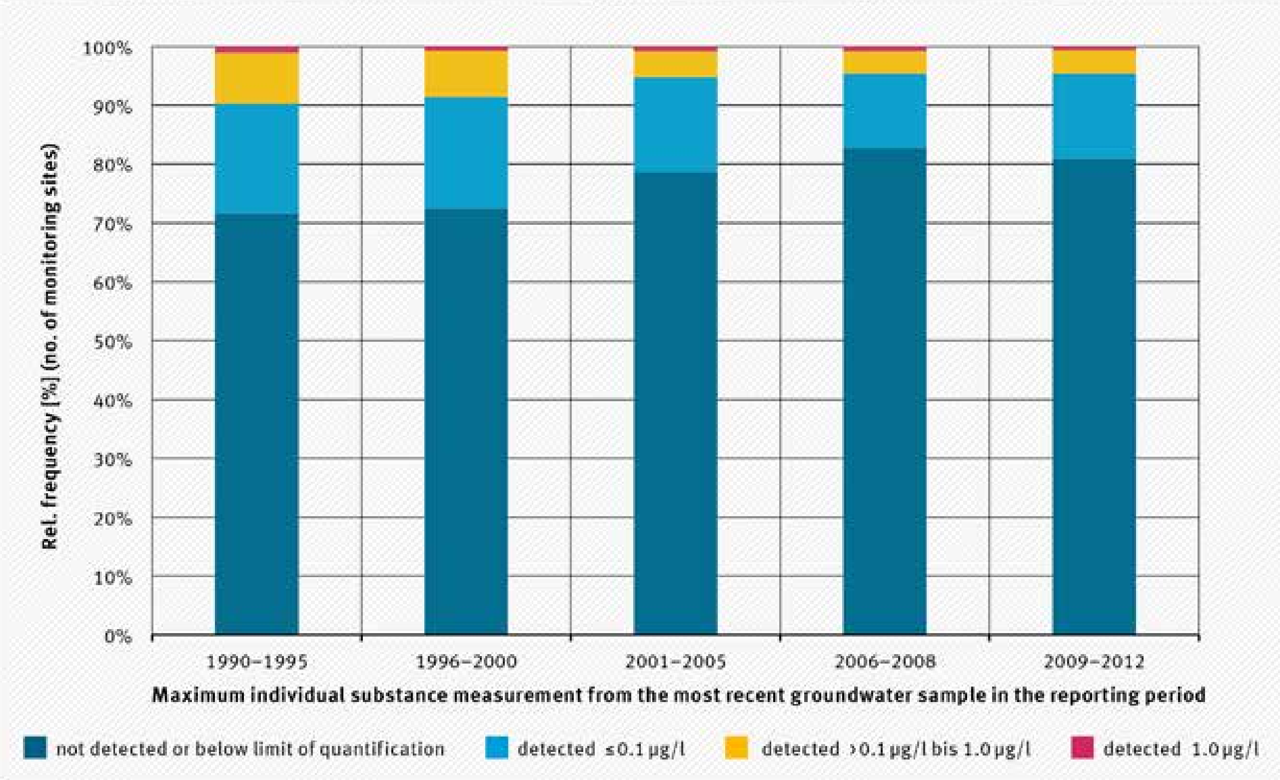
However, “non-relevant” does not mean that these substances are insignificant for groundwater. Just like other non-natural substances in groundwater, they are not desirable.

Since the initial findings were reported in 2006, the Laender have intensified their analyses of “non-relevant metabolites”, with the result that measurements from some 8,400 monitoring sites are now available for the period 2009 to 2012.

Around 55 % of monitoring sites found no indications of “non-relevant metabolites”; or put another way, “non-relevant metabolites” are found at almost one in every two monitoring sites. Most of the positive findings (Figure 6), at 21.7 %, are in the concentration range from 0.1 to 1.0 µg/l, while a further 10.5 % are above 1.0 µgl. Concentrations above 10.0 µg/l occur at 30 monitoring sites (0.4 %) (LAWA 2015a). Overall, “non-relevant metabolites” are found more frequently than active ingredients and relevant metabolites. As a precautionary measure, we should aspire to further reduce the concentrations of all “non-relevant metabolites” in groundwater. Given the high number of findings of non-relevant metabolites in groundwater, LAWA is calling for a nationwide threshold level for all “non-relevant metabolites” of 1.0 µg/l, or the equivalent of the health orientation value (HOV) specific to that substance.

Figure 5

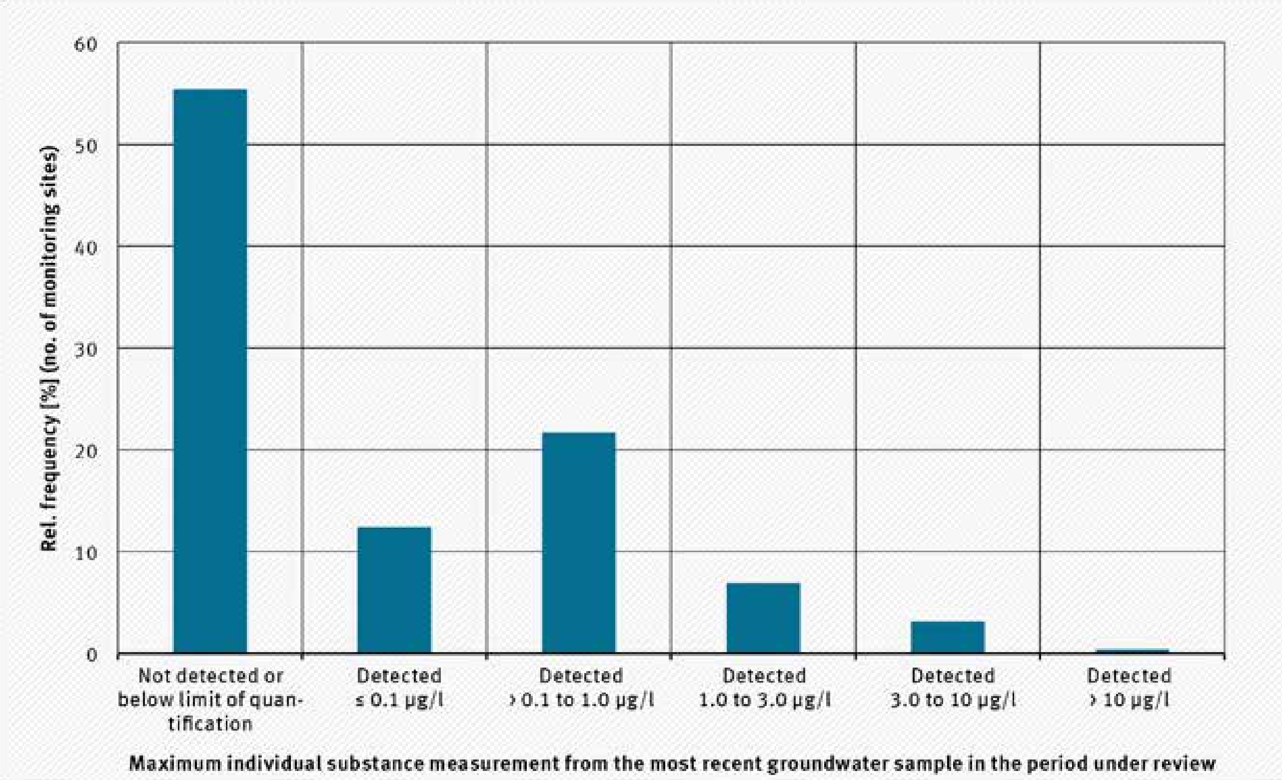
Frequency distribution of pesticide findings at superficially filtered groundwater monitoring sites in Germany



Source: German Environment Agency after LAWA 2015a

Figure 6

Frequency distribution of non-relevant metabolites at filtered superficial monitoring sites in Germany's groundwater



Source: German Environment Agency after LAWA 2015a

3.2.3 Groundwater ecosystems

Until now, as outlined above, the quality of groundwater has been assessed using physico-chemical and quantitative criteria. Unlike the quality assessment of surface waters, there is no traditional biological system from which an assessment of the ecological status of groundwater could be developed. Although groundwater is increasingly seen as a resource to be sustainably managed and an ecosystem with considerable natural capabilities and functionality that merits our protection, until now it has been viewed primarily from the perspective of water resource management. Statutory provisions and policy strategies are based primarily on protection concepts focusing on substances and usage. There is a lack of enforceable biological assessment criteria and analysis techniques that would enable us to gauge the influence of anthropogenic changes and their impacts on groundwater ecosystems.

In order to close this gap, the German Environment Agency initiated a multi-year research project to devise an initial, ecologically focused assessment system for groundwater ecosystems (UBA 2014).

The search for an appropriate ecological classification of groundwater systems

Until now, factors such as the aquifer type (porous aquifer, karst aquifer, and fractured aquifer), geology and permeability or productivity with regard to groundwater extraction were decisive in the classification of groundwater systems, and ecological criteria were ignored.

A key focus of the project was therefore to identify a spatially expedient classification of groundwater systems as the basis for an ecological assessment system analogous to the typology of surface waters. With this in mind, the team analysed the extent to which existing regional classification systems might be used for an ecosystem-based approach. Since the distribution of biotic communities does not follow any of the surface or subsurface classification systems tested, the researchers proposed a new classification scheme for groundwater ecosystems in Germany known as stygoregions.

Faunistic properties are the decisive factor in stygoregions (see Table 2).

Table 2

Features of Germany's stygoregion

Northern German Lowlands	Central German Uplands	South-Western Uplands	Northern Alps
Almost a complete absence of groundwater fauna, due to its very fine sediment and low oxygen levels	Diversity characterised by diverse fauna (27 species)	High diversity (32 species)	Medium diversity (15 species)
	Characterised by ubiquitous groundwater species and post-glacial recolonisers	High proportion of genuine groundwater fauna, larger species – isopods, niphargus	Reduced spectrum of groundwater species
	High proportion of groundwater-alien species (surface influence)	Low proportion of groundwater-alien species	Absence of groundwater-alien species

Source: UBA 2014

Derivation of reference conditions

Individual background levels were established for the sites analysed. Based on this, initial reference conditions for an ecologically intact groundwater aquifer were proposed. An ecologically intact aquifer is well-shielded against surface pollution and the groundwater is generally of drinking water quality. It is approximately characterised by reference conditions (see Table 3).

Groundwater fauna – minute, colourless and eyeless
Source: Karsten Grabow, PH Karlsruhe and Andreas Fuchs, Landau University

Table 3

Reference conditions for an intact groundwater aquifer

Fauna	Model groundwater aquifer
Proportion of crustaceans	≥ 70 %
Proportion of oligochaeta	≤ 20 %
Proportion of stygobionts (crustaceans)	› 50 %
GFI *	≤ 3
Microbiology	**Model groundwater aquifer**
CFUs [m/l]	≤ 500
BA [cells m/l]	Alluvium: ≤ 0.9*103 to 1.2*105, Karst: 3*103 to 4*105, Fissures: 4*103 to 1.5*105
BCP ** [ng C/(l h)]	≤ 0.5
ATP total [pM]	≤ 30
ATP intracellular [pM]	0.3–50
BOD_5 [mg/l]	≤ 1.5
E.coli [100 ml]	0

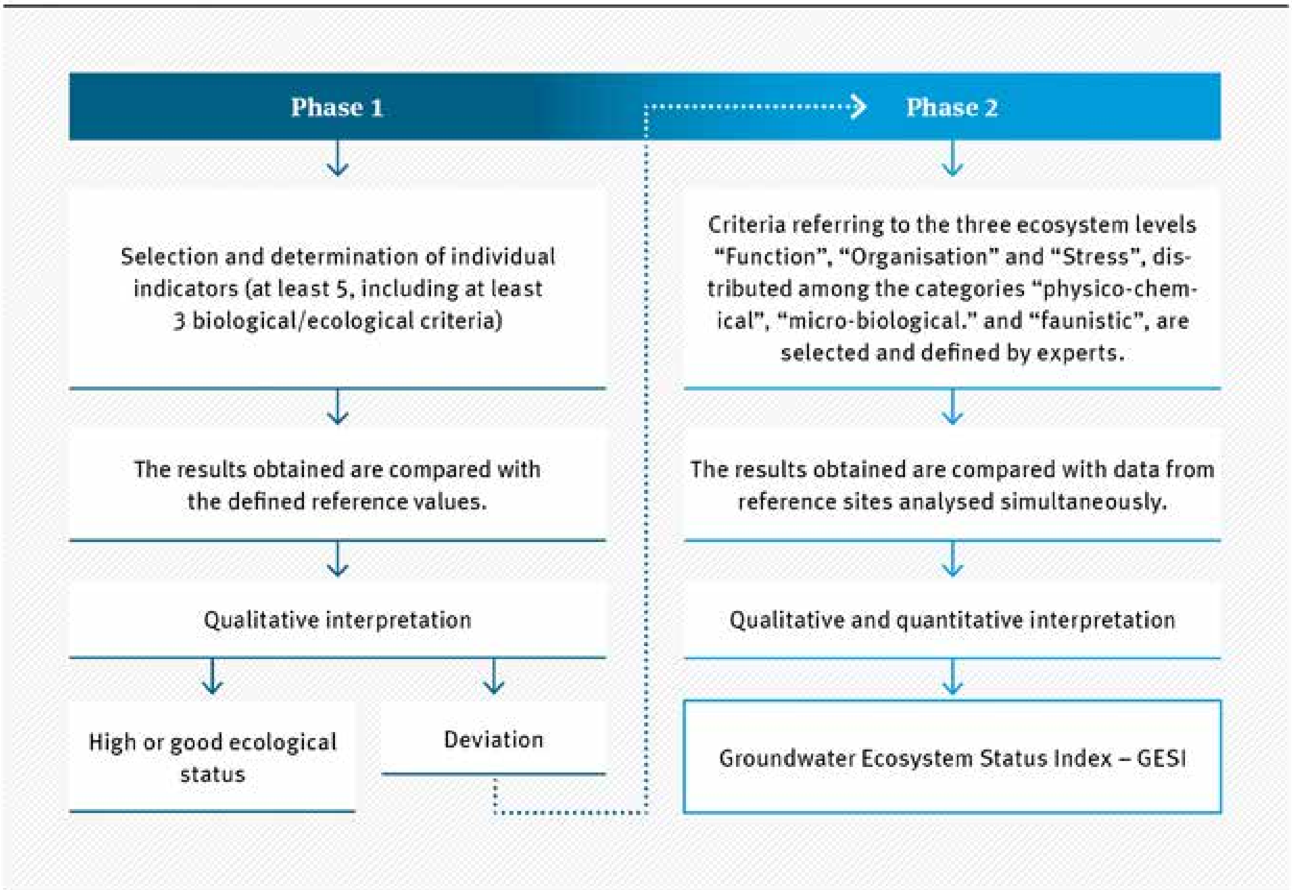
* The Groundwater Fauna Index (GFI) is a yardstick for measuring the ecologically relevant surface influence. The index values are calculated from the oxygen content, detritus volume and standard temperature deviation. Low index values indicate no or minimal surface influence, and vice versa.
** Bacterial carbon production (BCP) measures bacterial activity in groundwater.

Source: UBA 2014

Colony-forming units (CFU), bacterial abundance (BA) depending on the type of groundwater aquifer, adenosine triphosphate (ATP) production and biological oxygen demand (BOD) have emerged as the decisive variables for the purposes of microbiology.

Figure 7

Proposed two-phase assessment method



Source: UBA 2014

The surface influence can be assessed using selected faunistic measurement variables, allowing the groundwater quality of non-surface-influenced and surface-influenced samples to be compared on the basis of faunistic indicators. The following parameters are recommended as reference criteria: The Groundwater Fauna Index (GFI), the share of genuine groundwater organisms (stygionta) in the community should be more than 50 %, and the share of groundwater-alien species (oligochaeta) <20 %. Among stygobionta, the proportion of crustaceans should be >70 %, since studies indicate that the proportion of crustaceans is a particularly reliable measurement variable.

By combining all these sub-results, it was possible to develop a potential assessment method for a two-phase flowchart, whereby the complexity and meaningfulness increases significantly from phase 1 to phase 2 (Figure 7).

Due to the comparatively simple analysis work involved in phase 1, based on selected indicators and the background levels ascertained by the project, it is possible to determine whether the respective analysis site is in a "good status" or a "high status". In case of deviations, experts are consulted and detailed analyses carried out. Assessment according to phase 2 allows the calculation of an index and allocation to a quality category, already familiar from the ecological status assessment of surface waters (see Table 4).

This project has prompted significant progress towards a biologically-based assessment of groundwater status. The joint "GroundCare" project supported by the Federal Ministry for Education and Research will develop, test and standardise biological-ecological criteria and techniques for groundwater monitoring by 2018. GroundCare focuses on the following priority areas:

- The development, validation and standardisation of innovative criteria and methods for describing the ecological status of groundwater
- The standardisation of sampling records and implementation of assessment criteria for microbiological, molecular and faunistic groundwater evaluation
- The evaluation of ecosystem services with due regard for extreme weather events
- The development of an online method for ecotoxicological substance analysis in groundwater
- Compiling a guideline for the practical use of groundwater ecological assessment schemes.

Table 4

Proposed ecological quality categories for groundwater systems

Quality category	Ecological status	Comment
1	High	No anthropogenic interference ascertained, complies with the situation in reference monitoring sites
≥ 0.8 – < 1	Good	Deviation from the reference status is marginal and/or only temporary
≥ 0.6 – 0.8	Moderately impaired	The deviation from the reference status is estimated as minimal
≥ 0.4 – 0.6	Impaired	Significant deviation from a reference situation
≥ 0.2 – 0.4	Heavily impaired	Major anthropogenic interference ascertained, deviation from the reference situation in most of the selected parameters
0 – 0.2	Bad	Major anthropogenic interference ascertained, deviation from the reference situation in all or nearly all of the selected parameters

Source: UBA 2014


4

4 Assessment of surface waters

4.1 Bodies of surface water

Surface waters vary considerably in terms of the morphological, hydrological and geochemical characteristics, in their biotic communities, and in their sensitivity to anthropogenic influences. To take respect of this variability, the surface waters are divided into large-scale ecoregions and small-scale water body types, as well as into bodies of surface water. This subdivision is an ecological prerequisite for classification, as required by Article 5 and Annex II of the EU Water Framework Directive (WFD). The water body types are defined in Annex 1 to the Ordinance on Surface Waters of 2016.

The body of surface water is the unit of assessment and management. Bodies of surface water are delineated from one another if:

- The water body category (river, lake, transitional or coastal water) changes (for example, if a river flows into a lake)
- The water body type (see chapters 5.1.1, 6.1.1 and 7.1.1) changes
- The status changes (e.g. if a wastewater discharge causes the status to be downgraded from “good” to “moderate”).

Each body of surface water is generally allocated to a natural water body type. For each water body type, zoological and botanical reference lists are prepared of the species occurring in the natural state and their frequency. During assessment, the species found in the water bodies under current pressure conditions and their frequencies are compared against this yardstick.

As well as “natural” bodies of surface water, the WFD also distinguishes between “heavily modified” and “artificial” bodies of surface water. Bodies of surface water may be classified as “heavily modified” if their hydromorphological characteristics have been physically transformed to such an extent that their original reference status can no longer be expediently applied as an evaluation yardstick. For example, multiple dams in a heavily impounded river may cause that the water body is classed as “heavily modified water body” (HMWB) because damming changes the water body category from river to lake. Artificial water bodies (AWB) are man-made water bodies in locations where no water previously existed. In Germany, these are primarily open-cast mine lakes that have been created in former lignite mines, as well as dredged lakes, canals and drainage ditches. In heavily modified and artificial water bodies, anthropogenic use means that a “good ecological potential” is the required environmental objective, rather than a “good ecological status”.

4.2 Ecological and chemical status

The EU Water Framework Directive aims to achieve a good ecological and good chemical status of all bodies of surface water by no later than 2027. A natural water body has a good status if its ecological status and chemical status are assessed as “good”. Heavily modified water bodies and artificial water bodies have a good status if their ecological potential is at least “good” and their chemical status is assessed as “good”.

4.2.1 Ecological status and ecological potential

The EU Water Framework Directive adopts an integrative approach when assessing the ecological status of surface waters, focusing primarily on the presence of biotic communities typical of the natural area. Annex V lists the biological quality elements for the various water body types (Table 5) which must be taken into account when assessing ecological status. Hydromorphological and physico-chemical features play a supporting role in this assessment.

Table 5

Quality elements (QE) of ecological status as defined by the Water Framework Directive

Quality element	River	Lake	Transitional water	Coastal water
Biological quality elements				
Phytoplankton	X	X	X *	X
Large algae/angiosperms			X	X
Macrophytes/phytobenthos	X	X		
Macro-invertebrates	X	X	X	X
Fish	X	X	X	
Hydromorphological quality elements				
Continuity	X **			
Hydrology	X	X		
Morphology	X	X	X	X
Tidal regime			X	X
Chemico-physical quality elements				
General chemico-physical parameters	X	X	X	X
Specific pollutants	X	X	X	X

* Not available; this parameter cannot be assessed in German transitional waters of the North Sea due to the high level of turbidity.
** An assessment method for fish ladders, downstream fish passes and sediment continuity is currently under development.

Source: German Environment Agency in accordance with the Ordinance on Surface Waters (OGewV)

Key: Assessment not required; X Assessment method available; X Assessment method currently being trialled; X Assessment method not yet available

For assessing ecological status under the WFD, a range of methods has been developed for assessing the biological quality elements of ecological status. The parameters of these assessment methods include species composition and species frequency, age structure (fish) and biomass (phytoplankton).

The results of the national assessment methods were and still are compared with one another in a european-wide inter-calibration processes, and where necessary the class boundaries high/good and good/moderate were readjusted, in order to ensure that the same evaluation yardsticks are applied throughout every European country. This process is now complete for many national assessment methods, and all officially intercalibrated national assessment methods were incorporated into Annex 5 of the Ordinance on Surface Waters in 2016. A detailed overview and description of biological assessment methods may be found at http://www.gewaesser-bewertung.de.Intercalibration of the methods used to assess heavily modified and artificial bodies of surface water is still pending.

Ecological status comprises the following five classes: "high", "good", "moderate", "poor", and "bad" (see Table 6). The biological quality element with the worst assessment determines the ecological status (worst case approach). The quality element "specific pollutants" may lead to a downgrading of the ecological status. Exceeding even one environmental quality standard for river basin-specific pollutants (chapter 4.2.2) means that the ecological status/ecological potential can only be "moderate" at best, even if the biological quality elements are all "good" or better than good. Failure to comply with general physico-chemical parameter values may indicate potential ecological deficits or stressors. The assessment of hydromorphological quality elements is also used as an indicator of pressures, as well as for defining reference conditions.

Table 6

Representation of ecological status and ecological potential

Colour	Status	Potential *
	High	
	Good	Good and better
	Moderate	Moderate
	Poor	Poor
	Bad	Bad

* Potential is indicated on a large scale with grey hatching

Source: German Environment Agency in accordance with OGewV

Ecological classification is based on and derived from the reference conditions. The ecological status refers to a deviation from the reference conditions. Such deviations are defined in the EU Water Framework Directive and the Ordinance on Surface Waters, as follows:

- A **high status** indicates "no or only slight anthropogenic changes compared to the values" of the reference state. For this reason, both the biological quality elements and the physico-chemical and hydromorphological quality elements should represent virtually undisturbed conditions, and the environmental quality standard for specific pollutants should be met.

- For a **good ecological status**, all biological quality elements should exhibit no more than slight anthropogenic changes. In other words, they should deviate only slightly from the values that would exist in the absence of disturbing influences in the affected water body type. The environmental quality standards for all specific pollutants must be met. Furthermore, the values for general physico-chemical parameters should lie within a range which ensures proper functioning of the ecosystem.

- For a **moderate ecological status**, all biological quality elements must at least be in a "moderate state".

- If one or more of these biological quality elements is in a worse state, the water body must be classified as **poor** or **bad**.

For "heavily modified" and "artificial" water bodies, the EU Water Framework Directive prescribes the objective of "good ecological potential". "Maximum ecological potential" is the reference status for heavily modified water bodies. At maximum ecological potential, all measures have been taken to improve the morphology of the water body without restricting its anthropogenous usage. A "good ecological potential" represents only a minimal deviation of the biotic community from that of "maximum ecological potential".

4.2.2 Specific pollutants

An assessment of ecological status includes the consideration of specific pollutants. If these are discharged in significant quantities, the Member States must derive environmental quality standards to protect the aquatic communities (Annex V, 1.2.6 of Directive 2000/60/EC). To this end, chronic toxicity testing with algae, small crustaceans and fish fauna is carried out, and the most sensitive value selected. Since these organisms are representative of other organisms and biotic communities occurring in nature, compensating factors are taken into account when determining the environmental quality standard. If valid long-term toxicity tests are available for all trophic stages (food stages), this factor is 10. If data is missing, it will be 100 or more. For some substances, this leads to environmental quality standards for the "water" matrix which are below the detection levels in water. For such substances, which tend to be accumulable, compliance with the environmental quality standard in water cannot be verified. For this reason, in Germany, environmental quality standards for accumulable substances are primarily defined for the "suspended solid" matrix (Table 7).

In Germany, concentrations that exceed half the environmental quality standard at representative monitoring sites are considered significant. Annex 6 to the Ordinance on Surface Waters defines environmental quality standards with legally binding validity for 67 river basin-specific pollutants (see Table 7). It also states that in order to achieve a good status, the annual average must not exceed the annual average environmental quality standard (AA-EQS), and the maximum value must not exceed the maximum allowable concentration (MAC-EQS).

Table 7

Environmental quality standards (EQS) for specific pollutants to determine ecological status

Substance	CAS no.	AA-EQS [1]	MAC-EQS [1]	AA-EQS [1]	MAC-EQS [1]
		Rivers and lakes		Transitional and coastal waters	
Metals; dissolved concentration [2] in µg/l, suspended solids/sediment [3] in mg/kg					
Arsenic (As) (suspended solids/sediment)	7440-38-2	40		40	
Chromium (Cr) (suspended solids/sediment)	7440-47-3	640		640	
Copper (Cu) (suspended solids/sediment)	7440-50-8	160		160	
Selenium (Se), dissolved	7782-49-2	3		3	
Silver (Ag), dissolved	7440-22-4	0.02		0.02	
Thallium (Tl), dissolved	7440-28-0	0.2		0.2	
Zinc (Zn) (suspended solids/sediment)	7440-66-6	800		800	
Industrial chemicals; total concentration in µg/l					
1-Chloro-2-nitrobenzene	88-73-3	10		10	
1-Chloro-4-nitrobenzene	100-00-5	30		30	
Aniline	62-53-3	0.8		0.8	
Chlorbenzene	108-90-7	1		1	
Chloroacetic acid	79-11-8	0.6	8	0.06	2
Cyanide	57-12-5	10		10	
Nitrobenzene	98-95-3	0.1		0.1	
Phenanthrene	85-01-8	0.5		0.5	
Pesticides					
Fungicides; total concentration in µg/l, suspended solids/sediment [3] in µg/kg					
Carbendazim	10605-21-7	0.2	0.7	0.02	0.1
Dimoxystrobin	149961-52-4	0.03	2	0.003	0.2
Epoxiconazole	133855-98-8	0.2		0.2	
Fenpropimorph	67564-91-4	0.02	20	0.002	20
Propiconazole	60207-90-1	1		1	
Triclosan	3380-34-5	0.02	0.2	0.002	0.02
Triphenyl tin cation (suspended solids/sediment) [4]	668-34-8	20		20	
Herbicides; total concentration in µg/l					
2,4-D	94-75-7	0.2	1	0.02	0.2
Ametryn	834-12-8	0.5		0.5	
Bentazone	25057-89-0	0.1		0.1	
Bromacil	314-40-9	0.6		0.6	
Bromoxynil	1689-84-5	0.5		0.5	
Chlortoluron	15545-48-9	0.4		0.4	
Dichlorprop	120-36-5	0.1		0.1	
Diflufenican	83164-33-4	0.009		0.009	
Flufenacet	142459-58-3	0.04	0.2	0.004	0.02
Flurtamone	96525-23-4	0.2	1	0.02	0.1
Hexazinone	51235-04-2	0.07		0.07	
Linuron	330-55-2	0.1		0.1	
MCPA	94-74-6	2		2	
Mecoprop	7085-19-0	0.1		0.1	
Metazachlor	67129-08-2	0.4		0.4	

Substance	CAS no.	AA-EQS [1]	MAC-EQS [1]	AA-EQS [1]	MAC-EQS [1]
		Rivers and lakes		Transitional and coastal waters	
Methabenzthiazuron	18691-97-9	2		2	
Metolachlor	51218-45-2	0.2		0.2	
Metribuzin	21087-64-9	0.2		0.2	
Monolinuron	1746-81-2	0.2	20	0.02	2
Nicosulfuron	111991-09-04	0.009	0.09	0.0009	0.009
Picolinafen	137641-05-5	0.007		0.007	
Pyrazone (chloridazone)	1698-60-8	0.1		0.1	
Sulcotrione	99105-77-8	0.1	5	0.01	1
Terbuthylazine	5915-41-3	0.5		0.5	
Insecticides; total concentration in µg/l					
Azinphos-ethyl	2642-71-9	0.01		0.01	
Azinphos-methyl	86-50-0	0.01		0.01	
Diazinon	333-41-5	0.01		0.01	
Dimethoate	60-51-5	0.07	1	0.007	0.1
Etrimphos	38260-54-7	0.004		0.004	
Fenitrothion	122-14-5	0.009		0.009	
Fenthion	55-38-9	0.004		0.004	
Imidacloprid	105827-78-9 138261-41-3	0.002	0.1	0.0002	0.01
Malathion	121-75-5	0.02		0.02	
Omethoate	1113-02-6	0.004	2	0.0004	0.2
Parathion-ethyl	56-38-2	0.005		0.005	
Parathion-methyl	298-00-0	0.02		0.02	
Pirimicarb	23103-98-2	0.09		0.09	
Prometryn	7287-19-6	0.5		0.5	
Veterinary pharmaceuticals; total concentration in µg/l					
Phoxim	14816-18-3	0.008		0.008	
Substances under the Stockholm Convention (persistent organic pollutants (POP)); total concentration in µg/l, suspended solids/sediment [3] in µg/kg					
PCB-28 (suspended solids/sediment) [5]	7012-37-5	20		20	
PCB-52 (suspended solids/sediment) [5]	35693-99-3	20		20	
PCB-101 (suspended solids/sediment) [5]	37680-73-2	20		20	
PCB-138 (suspended solids/sediment) [5]	35065-28-2	20		20	
PCB-153 (suspended solids/sediment) [5]	35065-27-1	20		20	
PCB-180 (suspended solids/sediment) [5]	35065-29-3	20		20	

1) Unless otherwise specified, environmental quality standards are expressed as total concentrations in the total water sample.
2) The environmental quality standard refers to the dissolved concentration, i.e. the dissolved phase of a water sample obtained by filtration through a 0.45 µm filter or equivalent pre-treatment.
3) The environmental quality standards for suspended solids and sediment refer to the dry solid matter.
If suspended solids are extracted using a continuous centrifuge, the environmental quality standards refer to the total sample.
If sediment and suspended solids are extracted using sedimentation basins or collecting tanks, the environmental quality standards refer to
1. The fraction less than 63 µm in the case of metals.
2. The fraction less than 2 mm in the case of organic matter. With regard to organic matter, the findings from sediment samples may only be used for assessment purposes if more than 50% of the sediment samples have a fine grain proportion of below 63 µm.
4) Only where it is not possible to obtain data for suspended solids or sediment, a level of 0.0005 µg/l shall apply to the total concentration in the total water sample.
5) Only where it is not possible to obtain data for suspended solids or sediment, a level of 0.0005 µg/l shall apply to the total concentration in the total water sample.

Source: German Environment Agency in accordance with OGewV

4.2.3 Chemical status

The environmental quality standards for chemical status allow for the protection of aquatic organisms (including accumulation in the food chain) and human health. Tests with marine organisms were also used to derive environmental quality standards for coastal waters and seas. The marine protection conventions defined the goal of phasing out discharges of priority hazardous substances within one generation. The defined EU-wide environmental quality standards for the 45 priority substances listed in the EU Water Framework Directive and 5 further substances previously regulated on a European-wide basis, together with the action value for nitrate as defined under the EC Nitrates Directive, determine chemical status (Table 8). The regulations were adopted in Annex 8 to the Ordinance on Surface Waters. If the action value of 50 mg /l nitrate is exceeded, measures must be taken to reduce it.

The list of priority substances (Annex X to EU Directive 2000/60/EC) is revised every four years. In 2013, Directive 2013/39/EU adopted an update to Annex X and the Environmental Quality Standard Directive (Directive 2008/105/EC). It also extended the period for revising the list of substances to 6 years, in accordance with the management plans. The number of priority substances was increased from 33 to 45, 21 of which are classed as priority hazardous substances. The environmental quality standards for the 12 newly added priority substances will come into force in 2018, and should be met by 2027. The standards for eleven "old" substances have been amended.

There are two classes of chemical status. If the environmental quality standard is met, the status is "good" (labelled blue), otherwise it is "not good" (labelled red). "Good chemical status" as an environmental objective applies to both "natural" as well as "artificial" and "heavily modified" water bodies.

Priority substances must be measured if there are any emissions. The annual average is always monitored, hence the abbreviation AA-EQS (annual average – environmental quality standard). For selected pollutants with acute high toxicity, a maximum allowable concentration (MAC-EQS) is additionally specified, and must not be exceeded. For substances which indicate high levels of accumulation within the food chain, an environmental quality standard for biota (biota-EQS) was derived, and used primarily for assessment. Where biota-EQS and AA-EQS exist for the entire water phase for a given substance, in Germany, the AA-EQS may only be used as a basis for the classification of chemical status if biota data cannot be collected.

Reduced monitoring is admissible for the so-called ubiquitous, widespread substances brominated diphenyl ether, dioxins, hexabromocyclododecane, perfluorooctane sulfonate (PFOS), five polycyclic hydrocarbons, mercury and tributyltin compounds. European-wide monitoring of the substances on the so-called Watch List has additionally been introduced. The list includes substances with an identified potential to exceed the proposed environmental quality standard, for which insufficient European-wide monitoring data or data with a limit of quantification below the proposed environmental quality standard was available to warrant their inclusion in the list of priority substances. In Germany, the Laender are required to measure these substances at 24 monitoring sites. The first watch list was published in 2015 (EU COM 2015/495), and measurements followed in 2016. The EU Commission updates the watch list every 2 years (Directive 2013/39/EU).

Table 8

Environmental quality standards on chemical status for priority substances and other substances

Substance	CAS number	Priority hazardous substance	AA-EQS [1] in µg/l	AA-EQS [1] in µg/l	MAC EQS [1] in µg/l	MAC EQS [1] in µg/l	Biota EQS [2] in µg/kg wet weight
			rivers and lakes	Transitional and coastal waters	rivers and lakes	Transitional and coastal waters	Surface waters
Nutrients							
Nitrat (NO_3)			50,000				
Heavy metals							
Lead (Pb) and lead compounds	7439-92-1		1.2 [3]	1.3 [3]	14	14	
Cadmium (Cd) and cadmium compounds (depending on water hardness class) [4]	7440-43-9	X	≤0.08 (class 1) 0.08 (class 2) 0.09 (class 3) 0.15 (class 4) 0.25 (class 5)	0.2	≤0.45 (class 1) 0.45 (class 2) 0.6 (class 3) 0.9 (class 4) 1.5 (class 5)	≤0.45 (class 1) 0.45 (class 2) 0.6 (class 3) 0.9 (class 4) 1.5 (class 5)	
Nickel (Ni) and nickel compounds	7440-02-0		4 [3]	8.6 [3]	34	34	
Mercury (Hg) and mercury compounds	7439-97-6	X			0.07	0.07	20
Industrial chemicals							
Anthracene	120-12-7	X	0.1	0.1	0.1	0.1	
Benzene	71-43-2		10	8	50	50	
C10-13 chloro-alkanes [5]	85535-84-8	X	0.4	0.4	1.4	1.4	
1,2-Dichloroethane	107-06-2		10	10	not applicable	not applicable	
Dichloromethane	75-09-2		20	20	not applicable	not applicable	
Bis(2-ethyl-hexyl) phthalate (DEHP) [6]	117-81-7	X	1.3	1.3	not applicable	not applicable	
Fluoranthene	206-44-0		0.0063	0.0063	0.12	0.12	30
Naphthalene	91-20-3		2	2	130	130	
Nonylphenol (4-Nonylphenol)	84852-15-3 [7]	X	0.3	0.3	2	2	
Octylphenol [8] ((4-(1,1‘,3,3‘-Tetramethylbutyl)-phenol))	140-66-9		0.1	0.01	not applicable	not applicable	
Polycyclic aromatic hydrocarbons (PAH) [6), 9)]	not applicable	X	not applicable	not applicable	not applicable	not applicable	5
Benzo(a)pyrene	50-32-8		0.00017	0.00017	0.27	0.027	
Benzo(b)fluoranthene	205-99-2				0.017	0.017	
Benzo(k)fluoranthene	207-08-9				0.017	0.017	
Benzo(g,h,i)-perylene	191-24-2				0.0082	0.00082	
Indeno(1,2,3-cd)-pyrene	193-39-5				not applicable	not applicable	
Tetrachlorethylene	127-18-4		10	10	not applicable	not applicable	
Carbon tetrachloride	56-23-5		12	12	not applicable	not applicable	
Trichlorobenzenes [10]	12002-48-1		0.4	0.4	not applicable	not applicable	
Trichlorethylene	79-01-6		10	10	not applicable	not applicable	
Trichloromethane	67-66-3		2.5	2.5	not applicable	not applicable	

Substance	CAS number	Priority hazardous substance	AA-EQS [1] in µg/l rivers and lakes	AA-EQS [1] in µg/l Transitional and coastal waters	MAC EQS [1] in µg/l rivers and lakes	MAC EQS [1] in µg/l Transitional and coastal waters	Biota EQS [2] in µg/kg wet weight Surface waters
Pesticides							
Aclonifen	74070-46-5		0.12	0.012	0.12	0.012	
Alachlor	15972-60-8		0.3	0.3	0.7	0.7	
Atrazine	1912-24-9		0.6	0.6	2	2	
Bifenox	42576-02-3		0.012	0.0012	0.04	0.004	
Chlorfenvinphos	470-90-6		0.1	0.1	0.3	0.3	
Chlorpyrifos (chlorpyrifos-ethyl)	2921-88-2		0.03	0.03	0.1	0.1	
Cybutryne	28159-98-0		0.0025	0.0025	0.016	0.016	
Cypermethrin [11]	52315-07-8		0.00008	0.000008	0.0006	0.00006	
Dichlorvos	62-73-7		0.0006	0.00006	0.0007	0.00007	
Dicofol	115-32-2	X	0.0013	0.000032	not applicable	not applicable	33
Diuron	330-54-1		0.2	0.2	1.8	1.8	
Isoproturon	34123-59-6		0.3	0.3	1	1	
Quinoxyfen	124495-18-7	X	0.15	0.015	2.7	0.54	
Simazine	122-34-9		1	1	4	4	
Terbutryn	886-50-0		0.065	0.0065	0.34	0.034	
Tributyl tin compounds (tributyl tin cation) [6] (TBT)	36643-28-4		0.0002	0.0002	0.0015	0.0015	
Trifluralin	1582-09-8	X	0.03	0.03	not applicable	not applicable	
Substances in the Stockholm Convention (persistent organic pollutants (POP))							
Polybrominated diphenyl ether [6), 12] (BDEs)	32534-81-9	X			0.14	0.014	0.0085
DDT overall [13] (Total DDT) 4,4-DDT	not applicable 50-29-3		0.025 0.01	0.025 0.01	not applicable not applicable	not applicable not applicable	
Dioxins [14]		X					Sum of PCDD +PCDF +PCDL 0.0065 µg/kg TEQ [15]
Cyclodien pesticides (sum of aldrin, dieldrin, endrin, isodrin)	309-00-2 60-57-1 72-20-8 465-73-6		Σ = 0.01	Σ = 0.005	not applicable	not applicable	
Endosulfan [16]	115-29-7	X	0.005	0.0005	0.01	0.004	
Heptachlor and heptachlor epoxide	76-44-8/ 1024-57-3	X	0.0000002	0.00000001	0.0003	0.00003	0.0067
Hexabromcyclo-dodecane (HBCDD) [17]		X	0.0016	0.0008	0.5	0.05	167

Substance	CAS number	Priority hazardous substance	AA-EQS 1) in µg/l	AA-EQS 1) in µg/l	MAC EQS 1) in µg/l	MAC EQS 1) in µg/l	Biota EQS 2) in µg/kg wet weight
			rivers and lakes	Transitional and coastal waters	rivers and lakes	Transitional and coastal waters	Surface waters
Hexachlorocyclohexane 18) (HCHs)	608-73-1	X	0.02	0.002	0.04	0.02	
Hexachlorobenzene 6) (HCB)	118-74-1	X			0.05	0.05	10
Hexachlorbutadiene	87-68-3	X			0.6	0.6	55
Pentachlorobenzene 6)	608-93-5	X	0.007	0.0007	not applicable	not applicable	
Pentachlorophenol	87-86-5		0.4	0.4	1	1	
PFOS	1763-23-1	X	0.00065	0.00013	36	7.2	9.1

1) With the exception of cadmium, lead, mercury and nickel (metals), environmental quality standards are expressed as total concentrations in the total water sample. In the case of metals, the environmental quality standard refers to the dissolved concentration, i.e. the dissolved phase of a water sample obtained from filtration through a 0.45 µm filter or equivalent pre-treatment.

2) Unless otherwise indicated, the biota EQS refers to fish. For substance numbers 15 (Fluoranthene) and 28 (PAH), the biota EQS refers to crustaceans and molluscs. For substance number 37 (Dioxins and dioxin-like compounds), the biota EQS relates to fish, crustaceans and molluscs. If there are biota EQS and AA-EQS for the total water sample for a substance, the AA-EQS may only be used if biota data cannot be collected.

3) This EQS refers to bioavailable concentrations.

4) For cadmium and cadmium compounds the EQS values vary depending on the hardness of the water as specified in five class caterories (class 1: <40 mg $CaCO_3$/l, class 2: 40 to <50 mg $CaCO_3$/l, class 3: 50 to <100 mg $CaCO_3$/l, class 4: 100 to <200 mg $CaCO_3$/l and class 5: ≥200 mg $CaCO_3$/l). The hardness class derived from the 50 percentile of the $CaCO_3$ concentration calculated parallel to the cadmium concentration.

5) No indicative parameter is provided for this group of substances. The indicative parameter(s) must be defined through the analysis method.

6) The total content can also be calculated from measurements of the proportion adsorbed on the suspended solids. In such cases, the total content refers to
1. The total sample, in the case of sampling by centrifuge;
2. The fraction smaller than 2 mm, in the case of sampling by sedimentation basin or collecting tank. In such cases, a representative content of suspended solids should be calculated over the collection period.

7) Nonylphenol (CAS 25154-52-3, EU 246-672-0) including the isomers 4-Nonylphenol (CAS 104-40-5, EU 203-199-4) and 4-Nonylphenol (branched) (CAS 84852-15-3, EU 284-325-5).

8) Octylphenol (CAS 1806-26-4, EU 217-302-5) including the isomer 4-(1,1',3,3'-tetramethylbutyl)-phenol (CAS 140-66-9, EU 205-426-2).

9) In the group of polycyclic aromatic hydrocarbons (PAH), the biota EQS and the corresponding AA EQS in water refer to the concentration of benzo[a]pyrene, on the toxicity of which they are based. Benzo[a]pyrene can be considered a marker for the other PAHs, hence only benzo[a]pyrene needs to be monitored for comparison with the biota EQS and the corresponding AA-EQS in water.

10) Sum of 1,2,3-trichlorobenzene (TCB), 1,2,4-TCB and 1,3,5-TCB.

11) CAS 52315-07-8 refers to an isomer mixture of cypermethrin, α-cypermethrin (CAS 67375-30-8), β-cypermethrin (CAS 65731-84-2), ϑ-cypermethrin (CAS 71697-59-1) and ζ-cypermethrin (CAS 52315-07-8).

12) For the group of priority substances covered by polybrominated diphenyl ether (no. 5), the EQS refers to the sum total of concentrations of congener numbers BDE28 (CAS 41318-75-6), BDE47 (CAS 5436-43-1), BDE99 (CAS 60348-60-9), BDE100 (CAS 189084-64-8), BDE153 (CAS 68631-49-2) and BDE154 (CAS 207122-15-4). Only tetrabromodiphenyl ether (CAS 40088-47-9), pentabromodiphenyl ether (CAS 32534-81-9), hexabromodiphenyl ether (CAS 36483-60-0 and heptabromodiphenyl ether (CAS 68928-80-3) are classified as priority hazardous substances.

13) DDT total comprises the sum of isomers 4,4-DDT (CAS 50-29-3; EU 200-024-3), 2,4-DDT (CAS 789-02-6; EU 212-332-5), 4,4-DDE (CAS 72-55-9; EU 200-784-6) and 4,4-DDD (CAS 72-54-8; EU 200-783-0).

14) This refers to the following compounds:
7 polychlorinated dibenzo-para-dioxins (PCDDs): 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8-H6CDD (CAS 39227-28-6), 1,2,3,6,7,8-H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9)

10 polychlorinated dibenzofurans (PCDFs): 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8,-P5CDF (CAS 57117-41-6), 2,3,4,7,8,-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8,-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918-21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0)

12 dioxin-like polychlorinated diphenyls (PCB-DL): 3,3',4,4'-T4CB (PCB 77, CAS 32598-13-3), 3,3',4',5-T4CB (PCB 81, CAS 70362-50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS no. 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS no. 65510-44-3), 3,3',4,4', 5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5'-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3',4,4',5,5'-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5',-H7CB (PCB 189, CAS 39635-31-9).

15) PCDD: Polychlorinated dibenzo-para-dioxins; PCDF: polychlorinated dibenzofurans; PCB-DL: dioxin-like polychlorinated biphenyls; TEQ: toxic equivalents according to the World Health Organisation 2005 Toxic Equivalence Factors'; van den Berg, M (2006) et al.: the 2005 World Health Re-evalution of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds published in toxicological sciences 93(2); 223-241 (2006)

16) The environmental quality standard refers to the sum total of the two (stereo-)isomers alpha-endosulfan (CAS 295-98-8) and beta-endosulfan (CAS 33213-65-9).

17) 1,3,5,7,9,11-HBCDD (CAS 25637-99-4), 1,2,5,6,9,10-HBCDD (CAS 3194-55-6), α-HBCDD (CAS 134237-50-6), β-HBCDD (CAS 134237-51-7) and γ-HBCDD (CAS 134237-52-8)

18) Sum of isomers α-, β-, γ- and δ-HCH.

Source: German Environment Agency in accordance with OGewV

4.3 Monitoring programmes

Article 8 of the WFD obligates the European Union Member States to prepare programmes for monitoring the status of water bodies in order to obtain a cohesive and comprehensive overview of the status of water bodies in river basins. The fundamental requirements governing the monitoring of surface waters (rivers, lakes, transitional and coastal waters) are set out in Annex V to the EU Water Framework Directive. Key aspects here include the monitoring types and objectives, the choice of monitoring sites, the quality elements to be monitored, and the required monitoring frequencies (Annex V 1.3 to EU Directive 2000/20/EC). LAWA drew up the "framework concept for the preparation of monitoring programmes and for evaluating the status of surface waters" to ensure the coherent structuring of monitoring programmes in Germany (LAWA 2012a). The provisions of the WFD and several provisions from the framework concept were incorporated into the Ordinance on Surface Waters.

The WFD monitoring network should be designed in such a way as to facilitate European-wide comparability of the analysis results and an overview of the ecological and chemical status of surface waters in the river basins. Essentially, the monitoring programmes pursue the following objectives:

- Reviewing compliance with environmental targets
- Creating the essential foundations for the planning of measures, reporting and monitoring the success of measures implemented
- Monitoring long-term natural and anthropogenic developments, and
- Determining the magnitude and impacts of unintentional contamination.

Depending on the task in question, we distinguish between the following forms of monitoring:

- Surveillance monitoring
- Operational monitoring
- Investigative monitoring.

The quality elements to be analysed, monitoring frequency and intervals for surveillance monitoring and operational monitoring are set out in Annex 10 to the Ordinance on Surface Waters. Monitoring sites for investigative monitoring purposes are generally set up for a limited period alongside operational monitoring sites if it is unclear why a water body has failed to meet a target, or in order to determine the extent and impacts of unintentional contamination in the water body. The parameters, monitoring frequency and intervals, together with the duration of monitoring, are determined on a case-by-case basis (LAWA 2012a).

The monitoring networks for surveillance monitoring and operational monitoring differ, among other things, in the scope of parameters, cycle and duration of monitoring site operation (see Table 9).

Table 9

Criteria for monitoring sites in surveillance monitoring and operational monitoring

	Monitoring network for surveillance monitoring	Monitoring network for operational monitoring
Selection of monitoring site	Representative of the river basin district or sub-basin	Depending on the pressure situation
Selection of quality elements	All	Depending on the pressure situation
Cycle	Uniform for the monitoring sites in a river basin district/sub-basin	Depending on the pressure situation
Duration of operation	Permanent	Depending on the pressure situation

Source: German Environment Agency according to LAWA 2012a

Whereas surveillance monitoring incorporates all quality elements, operational monitoring only requires the monitoring of those quality elements which react most sensitively to pressures in the body of surface water. Biological quality elements are the most frequently analysed. Operational monitoring is also used to monitor the success of any measures implemented. Long-term data series are available for the majority of surveillance monitoring sites, and will be continued, enabling conclusions to be drawn on the development of pressures.

Rivers in the Alpine upper reaches
Source: German Environment Agency (UBA)

5

5 Rivers

5.1 Basis for assessment

5.1.1 Stream- and River-Types

Our flowing waters (streams and rivers) are distinguished by their characteristic biotic communities depending on the geological, physico-chemical and hydrological conditions. On this basis, there are currently 25 defined stream- and river-types (with further sub-types) in Germany (see Table 10):

- Four types for the eco-region of the Alps and Alpine foothills
- Eight types for the Central German Highlands (Mittelgebirge)
- Nine types for the North German Lowlands and
- Four types further stream- and river-types that are distributed among various ecoregions as “ecoregion-independent types”.

Among individual types, further sub-types have been designated that are relevant for assessment purposes, e.g. due to differences along their length. Descriptions of the stream- and river-types have been drawn up in the form of “characteristics profiles”, including a brief characterisation of the morphological conditions and the biotic communities of the organism groups used for evaluation purposes (biological quality element).

Table 10

Biocoenotically relevant stream- and river-types in Germany

Transverse structure in the Mulde (Raguhn)

Types in the Alps and the Alpine foothills	Sub-types
Type 1: Alpine streams	Sub-type 1.1: Small rivers of the Calcareous Alps Sub-type 1.2: Mid-sized rivers of the Calcareous Alps
Type 2: Streams in the Alpine foothills	Sub-type 2.2: Small rivers in the Alpine foothills Sub-type 2.2: Mid-sized rivers in the Alpine foothills
Type 3: Streams in the Pleistocene sediments of the Alpine foothills	Sub-type 3.1: Small rivers in the Pleistocene sediments of the Alpine foothills Sub-type 3.2: Mid-sized rivers in the Pleistocene sediments of the Alpine foothills
Type 4: Large rivers in the Alpine foothills	
Types from the Central German Highlands	**Sub-types**
Type 5: Coarse substrate-dominated, siliceous small highland rivers	
Type 5.1: Fine substrate-dominated, siliceous small highland rivers	
Type 6: Fine substrate-dominated, calcareous small highland rivers	Sub-type 6_K: Fine substrate-dominated, calcareous small highland rivers in the Keuper
Type 7: Coarse substrate-dominated, calcareous small highland rivers	
Type 9: Siliceous, fine to coarse substrate-dominated mid-sized highland rivers	
Type 9.1: Calcareous, fine to coarse substrate-dominated mid-sized highland rivers	Sub-type 9.1_K: Calcareous, fine to coarse substrate-dominated, mid-sized highland rivers in the Keuper
Type 9.2: Large highland rivers	
Type 10: Gravel-dominated, very large rivers	
Types in the North German lowlands	**Sub-types**
Type 14: Sand-dominated small lowland rivers	
Type 15: Sand and loam-dominated mid-sized lowland rivers	
Type 15_g: Sand and loam-dominated large lowland rivers	
Type 16: Gravel-dominated small lowland rivers	
Type 17: Gravel-dominated mid-sized lowland rivers	
Type 18: Loess and loam-dominated small lowland rivers	

Type 20: Sand-dominated very large rivers	
Type 22: Marshland streams of the coastal plains	Sub-type 22.1: Waters of the marshes Sub-type 22.2: Rivers of the marshes Sub-type 22.3: Very large rivers of the marshes
Type 23: Baltic Sea tributaries influenced by backflow or brackish waters	
Ecoregion-independent types	**Sub-types**
Type 11: Organic substrate-dominated small rivers	
Type 12: Organic substrate-dominated mid-sized rivers	
Type 19: Small streams in riverine floodplains	
Type 21: Lake outflows	Sub-type 21_N: Lake outflows in the North German lowlands (north) Sub-type 21_S: Lake outflows in the Alpine foothills (south)

Source: German Environment Agency in accordance with Annex 1 of the Ordinance on Surface Waters (OGewV)

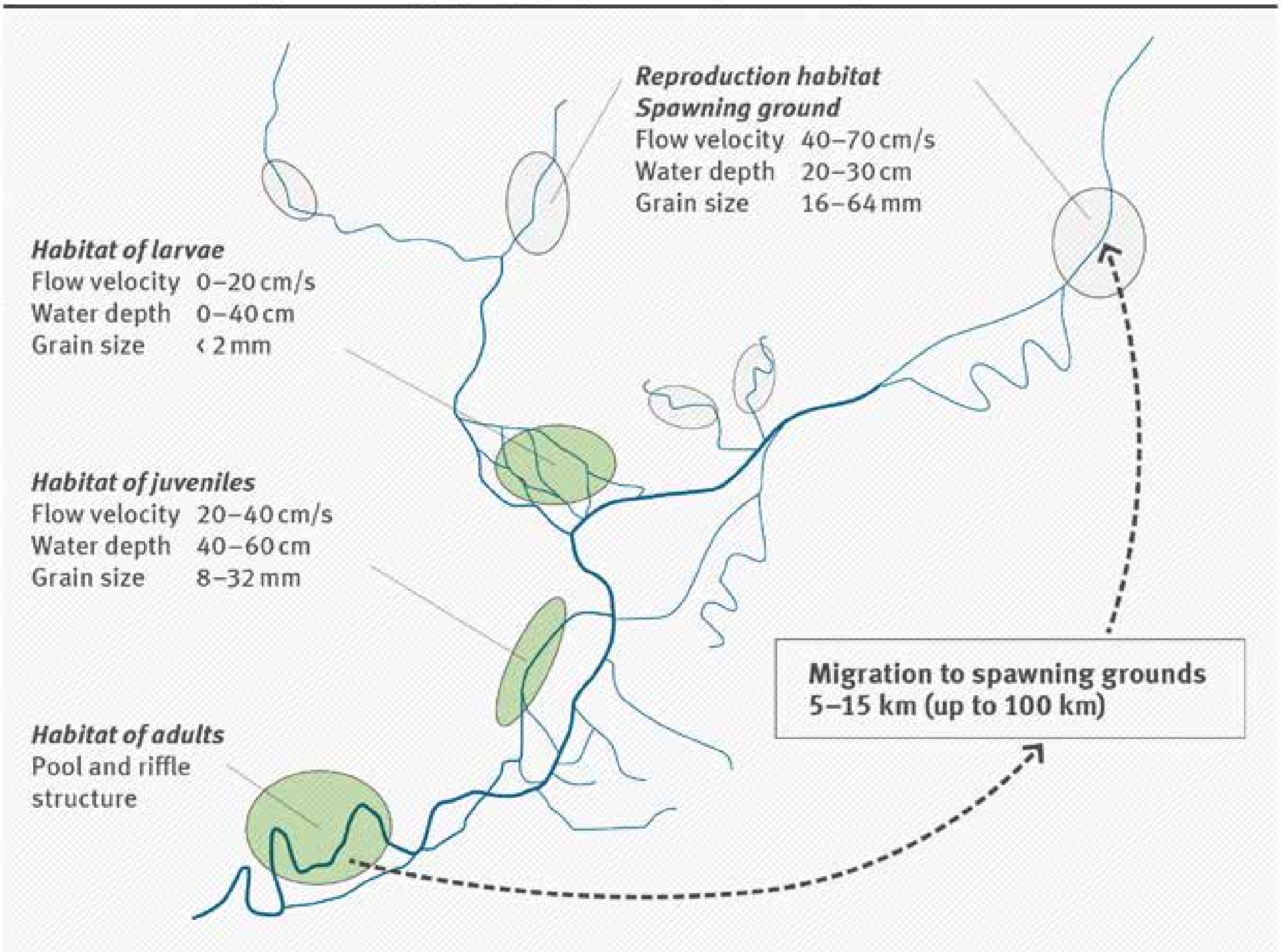
5.1.2 Biological quality elements

Biological quality elements are the principal elements used for assessing ecological status, and comprise invertebrates, fish, macrophytes, phytobenthos and phytoplankton (see chapter 4.2.2). The worst-rated quality element determines the overall assessment of a water body's ecological status (one out – all out principle). The assessment methods used for biological quality elements under the EU Water Framework Directive (WFD) are set out in Annex 6 to the Ordinance on Surface Waters. Detailed descriptions of all biological assessment methods are available for downloading at http://www.gewaesser-bewertung.de.

Small highland river close to the source
Source: Stephan Naumann

Figure 8

Habitats in the lifecycle of the grayling (Thymallus thymallus L.)



Source: German Environment Agency

5.1.3 Hydromorphological quality elements

The hydromorphological quality elements of the Water Framework Directive are morphology, hydrological regime and continuity. Hydromorphological quality elements are not primarily decisive for assessing the status of a water body, but they must be of a sufficient quality that the biological quality elements are able to achieve a good ecological status.

The migratory patterns of many fish species are a good example. For example, reproduction places have different requirements on environmental factors such as flow, temperature and substrate than on feeding, maturation or winter dormancy. For this reason, native species migrate within connected water systems to find the optimum conditions for their current life phase (Figure 8). These species are dependent on the continuity of their river and its links to all required sub-habitats. The fragmentation of flowing waters primarily affects the species composition of fish fauna.

Hydromorphological quality elements are directly relevant to assessment in cases where the water body is to be classified as having a high ecological status, when certain normative requirements must be satisfied. Nevertheless, experts agree that water body hydromorphology is a value in its own right, and is fundamental to the assessment and description of the pressure situation of a section of river and for deriving measures to improve habitats. Dedicated classification methods have been and are being developed for morphological conditions, hydrological regime and continuity.

Morphological conditions and watercourse structure

Morphological status is ascertained using the watercourse structure mapping technique, which determines the deviation of the current morphological structure from its potential natural form. Watercourse structure refer collectively to all spatial and material differentiations in the riverbed, riparian area and surrounding land which affect hydraulics, morphology and hydrobiology, and which are significant to the ecological functioning of the river and its floodplain. The term "potential natural" status is used if the water body develops its own natural dynamics, all river engineering measures are reversed, and material emissions are reduced to the naturally occurring level. The potential natural status includes irreversible changes to the watercourse landscape, such as irreversible sedimentation processes (the silting up of lakes due to excess primary production), or the formation of alluvial loam in river valleys due to denudation (extensive erosion) of soils following extensive forest clearance in medieval times. The extent by which a watercourse's morphological conditions deviate from the potential natural status is assigned to one of seven structural classes (Table 11). Water bodies which indicate no or only slight changes to their natural structure and dynamics are classified as structural class 1. At the other end of the scale, water bodies in structural class 7 are considered to have been completely altered and furthest removed from their potential natural state.

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Table 11

Structural classes of water bodies

Category	Degree of change	Brief description
1	unchanged	The water body structure corresponds to the potential natural state
2	slightly changed	The water body structure is influenced only minimally by isolated, small-scale interventions.
3	moderately changed	The water body structure is influenced only moderately by several small-scale interventions.
4	distinctly changed	The water body structure is significantly influenced by various interventions e.g. in the bed, bank, by backflow and/or uses in the flood plain.
5	obviously changed	The water body structure is impaired by a combination of interventions e.g. into its routing, as a result of bank obstruction, transverse structures, dam regulation, flood alleviation installations and/or use in the flood plain.
6	strongly changed	The water body structure is heavily impaired by a combination of interventions e.g. into its routing, as a result of bank obstruction, transverse structures, dam regulation, flood alleviation installations and/or use in the flood plain.
7	completely changed	The water body structure has been completely transformed as a result of various interventions into its routing, bank obstruction, transverse structures, dam regulation, flood alleviation installations and/or use in the flood plain.

Source: LAWA 2002

On small to medium-sized watercourses, the morphological structure is assessed using either the "overview method" or the "on-site method" (LAWA 2000; 2001; 2014d). These methods focus on those structural elements of a watercourse with particular relevance to assessment (see Table 12) which have certain indicator properties. For example, most lowland water bodies develop a meandering course which entails cutting off meanders and oxbows. The structural quality of a lowland river can therefore be described in terms of how much its course meanders. If this is inadequately developed or has been altered by means of straightening measures, the assessment will be downgraded. Individual assessments are aggregated at various functional levels and ultimately combined to form a structural class.

Table 12

Individual parameters and aggregation levels under the on-site method for small and medium-sized watercourses

Area	Main parameter	Functional unit	Individual parameter
Riverbed	Course development	Meandering	**Meandering**
			Longitudinal banks
			Special run structures
		Mobility	**Meandering erosion**
			Profile depth
			Bank obstruction
	Longitudinal profile	Natural longitudinal profile elements	**Transverse banks**
			Flow diversity
			Depth variance
		Anthropogenic barriers	Transverse structures
			Piping
			Openings
			Backflow
	Bed structure	Nature and distribution of substrate	Substrate type
			Substrate diversity
			Specialised structures
		Bed obstruction	Bed obstruction
Bank	Cross-section	Profile depth	**Profile depth**
		Width development	**Width erosion**
			Width variance
		Profile shape	Profile shape
	Bank structure	Typical features of the natural area	**Special bank structures**
		Plant growth typical of the natural area	**Bank growth**
		Bank obstruction	**Bank obstruction**
Land	Surrounding area	Riparian buffer strips	**Riparian buffer strips**
		Foothills	Land use
			Other surrounding structures

Individual parameters highlighted in bold are used for reporting under the EU Water Framework Directive.

Source: LAWA 2002

Under the Water Framework Directive, a simplified set of 18 individual morphological parameters (Table 12) is used to report on the status of the hydromorphological quality element "morphology". Assessment is based on a 5-point classification scale for water body structure, derived from an equidistant transformation of the 7-point structural quality method into 5 categories (LAWA 2012b).

The terms "potential natural status" and "hydromorphological reference conditions" are used synonymously, and are described in detail in profiles of morphological and biocoenotic watercourse types (Dahm et al. 2014). When determining the reference and deriving measures, it is important to consider a watercourse's land requirements. A watercourse needs sufficient land in order to develop a structural inventory that reflects its size, gradient, geology and climate. A method for determining this type-specific hydromorphological land requirement is now available (LAWA 2016b).

Hydrology

The hydrology of a watercourse is classified using the parameters "discharge and discharge dynamics" and "connection to groundwater bodies". Hydrologically relevant intervention and pressure types are used for classification purposes. These include uses in the catchment area, water abstractions, water discharges, river engineering measures and structures in the water, changes to floodplains and other pressures. The extent to which the ecosystem is capable of resisting or compensating for a pressure is also taken into account. For assessment purposes, the intensity of a given pressure is related to the potential natural status. This assessment is made on the basis of data or expert knowledge. Each watercourse body is classified individually into five classes, based on the "one out – all out principle" (LAWA 2014b; 2014c). The procedure is currently undergoing practical trials and will be used at the end of the second WFD management cycle to assess hydrology.

Continuity

A method is being developed by the German Working Group on water issues of the Laender and the Federal Government (LAWA) to classify the continuity of watercourses. It will include an assessment of continuity for fish upstream and downstream migration and sediment continuity in relation to the barrier, the water body and the river system. There are plans to develop a 5-point scale analogous to those used for the classification of morphology and hydrology (Keuneke and Donner 2016).

5.1.4 General physico-chemical quality elements

Annex V of the Water Framework Directive lists visibility, temperature, oxygen, conductivity, acidification and nutrient conditions as general physico-chemical quality elements for streams and rivers. In a "high status", the defined type-specific background levels of these general physico-chemical quality elements must be adhered to. In a "good status" the values must be within a range which guarantees correct functioning of the type-specific ecosystem and type-specific population with at least a good biological quality classification ("threshold values"). If these threshold values are not met, the result of the biological quality elements should be reviewed if a "good" ecological status is indicated. Annex 7 to the Ordinance on Surface Waters sets out water body type-specific background (very good status) and threshold values (values for good status/good ecological potential) for various parameters of general physico-chemical quality elements (see http://www.gewaesser-bewertung.de/index.php?article_id=145&clang=0).

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

5.1.5 Other assessment methods

As well as the legally binding environmental quality standards defined in Annexes 6 and 8 and the values provided in Annex 7 to the Ordinance on Surface Waters, the 7-point chemical water quality classification provides an important basis for assessing the pollution of inland surface waters in Germany. The Federation and Laender developed this water quality classification prior to the Water Framework Directive's entry into force. For total phosphorus and ammonia nitrogen, the classification has been amended in line with Annex 7 of the Ordinance on Surface Waters (see chapter 5.1.4). The upper class limit of quality class II is the type-specific threshold value. Quality class I represents background levels, while quality class I-II is the mean of quality classes I and II. The following upper class limits are obtained by multiplying the target value (quality class II) by a factor of 2. The classifications listed in Tables 13 and 14 for the surface water types at LAWA measuring sites are derived from these definitions. In the case of lakes in river-lake systems (lake type 12), quality classes I and I–II have currently been waived. Annual averages are used for grouping into classes.

Table 13

Quality classification for total phosphorus in mg/l, comparison value: Annual average

Surface water type	I	I–II	II	II–III	III	III–IV	IV
1.1, 1.2, 2.2, 3.2, 4, 5, 9, 9.1, 9.1K, 9.2, 10, 14, 15, 15g, 16, 17, 20, 23	≤0.05	≤0.075	≤0.1	≤0.2	≤0.4	≤0.8	>0.8
12, 19	≤0.05	≤0.1	≤0.15	≤0.3	≤0.6	≤1.2	>1.2
22.1, 22.2, 22.3	≤0.1	≤0.2	≤0.3	≤0.6	≤1.2	≤2.4	>2.4
T1, T2	≤0.03	≤0.0375	≤0.045	≤0.09	≤0.18	≤0.36	>0.36
Lake type 12 *	–	–	≤0.1	≤0.2	≤0.4	≤0.8	>0.8

* Comparison value: Mean for the period from April to October

Source: German Environment Agency after LAWA 1998 and OGewV

Table 14

Quality classification for ammonia nitrogen in mg/l, comparison value: Annual average

Surface water type	I	I–II	II	II–III	III	III–IV	IV
1.1, 1.2, 2.2, 3.2, 4, 5, 9, 9.1, 9.1K, 9.2, 10, 12, 14 [1)], 16 [1)], 19 [2)]	≤0.04	≤0.075	≤0.1	≤0.2	≤0.4	≤0.8	>0.8
12 [3), 4)], 14 [5)], 15, 15g, 16 [5)], 17, 19 [4)], 20, 23	≤0.04	≤0.1	≤0.2	≤0.4	≤0.8	≤1.6	>1.6
22.1, 22.2, 22.3	≤0.04	≤0.2	≤0.3	≤0.6	≤1.2	≤2.4	>2.4

1) Silicatic 2) In the Central German Highlands 3) Base-rich 4) In the Northern German lowlands 5) Carbonatic

Source: Stephan Naumann

Source: German Environment Agency after LAWA 1998 and OGewV

As long as there are no binding values available for classification as good ecological status for nitrate, Germany will continue to apply the current holistic chemical water quality classification (Table 15), which also takes into account remote effects in the oceans (this extends to reporting under the EU Nitrates Directive). The substance concentrations corresponding to quality class I characterise a status that is free from anthropogenic impairments. Quality class II contains values derived from previous assessment procedures. The other upper class limits are ascertained in the same way as for total phosphorus and ammonia nitrogen (a factor of 2). Grouping into classes is based on the 90 percentile.

Table 15

Quality classification for nitrate nitrogen in mg/l, comparison value: 90 percentile

Surface water type	I	I–II	II	II–III	III	III–IV	IV
All surface water type	≤1	≤1.5	≤2.5	≤5	≤10	≤20	>20

Source: LAWA 1998

5.1.6 Monitoring networks for reporting

The LAWA network of monitoring sites has been set up in Germany for the purposes of reporting on European Directives and reporting to the European Environment Agency. In 2008, the LAWA network of monitoring sites for flowing waters was extended to include new monitoring sites in the surveillance monitoring network, and currently comprises some 257 representative monitoring sites, primarily surveillance monitoring sites together with some in the operational monitoring network, monitoring sites for investigative purposes, and reference monitoring sites on flowing waters, transitional waters and one river-lake (cf. also chapter 4.3). The data from these monitoring sites provides the basis for the assessments in chapters 5.2.2-5.2.6 and 5.2.8

5.2 Status assessment

5.2.1 Ecological status

The objectives of the WFD apply to all water bodies. Rivers with a catchment area of more than 10 km^2 for which reporting is mandatory under the Water Framework Directive have a watercourse length of around 137,000 kilometres. They have been divided into 9,885 water bodies (LAWA 2016b). The following assessments refer to the watercourse lengths.

The watercourse length of all natural streams and rivers totals approximately 83,800 km, corresponding to 61 % of the total stream and river length. The proportion of heavily modified water bodies (HMWB) is 29 %, while artificial water bodies (AWB) account for 10 %.

In relation to the assessed watercourse length, around 9 % of all natural stream and river water bodies currently exhibit a high or good ecological status. Among heavily modified and artificial watercourses, only 2 % and 5 % respectively, in terms of the assessed watercourse length, exhibit a good or high ecological potential (Figure 9).

The proportion of natural water bodies assessed equates to 99 % of total stream and river length. Of this (see also Figures 9–11):

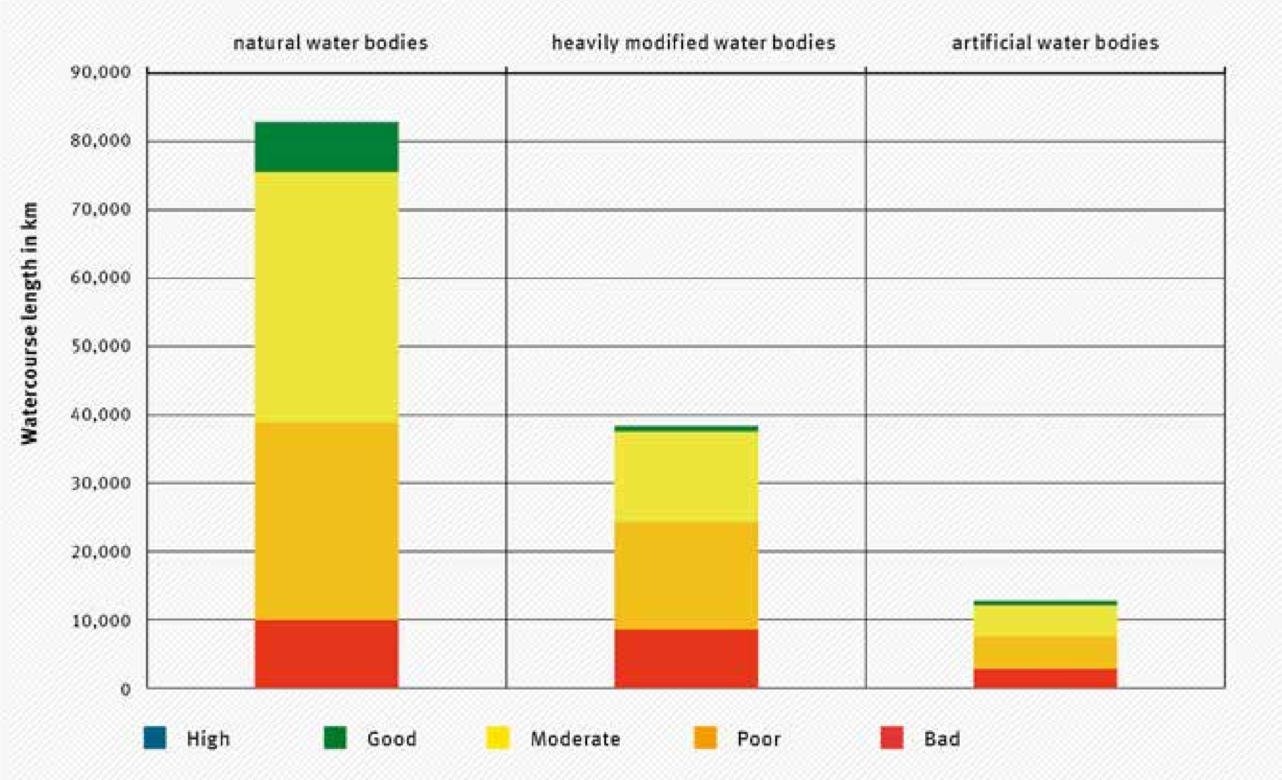
- Approximately 100 km of Alpine streams and small highland rivers (0.1 %) exhibit a "high" ecological status
- Approximately 7,300 km (9 %) exhibit a "good" status, with Alpine streams having the highest share, at around 50 % of their watercourse length
- Approximately 36,700 km (44 %) exhibit a "moderate" ecological status
- Approximately 2,900 km (35 %) exhibit a "poor" ecological status
- Approximately 9,900 km (12 %) exhibit a "bad" ecological status; only Alpine streams and rivers have no natural watercourse length with a bad ecological status (LAWA 2016b).

The most common reason for failing to achieve a "good ecological status" in natural water bodies are high levels of nutrient load originating from human activities and changes to hydromorphology, which is reflected in changes to the natural aquatic community of that area.

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Figure 9

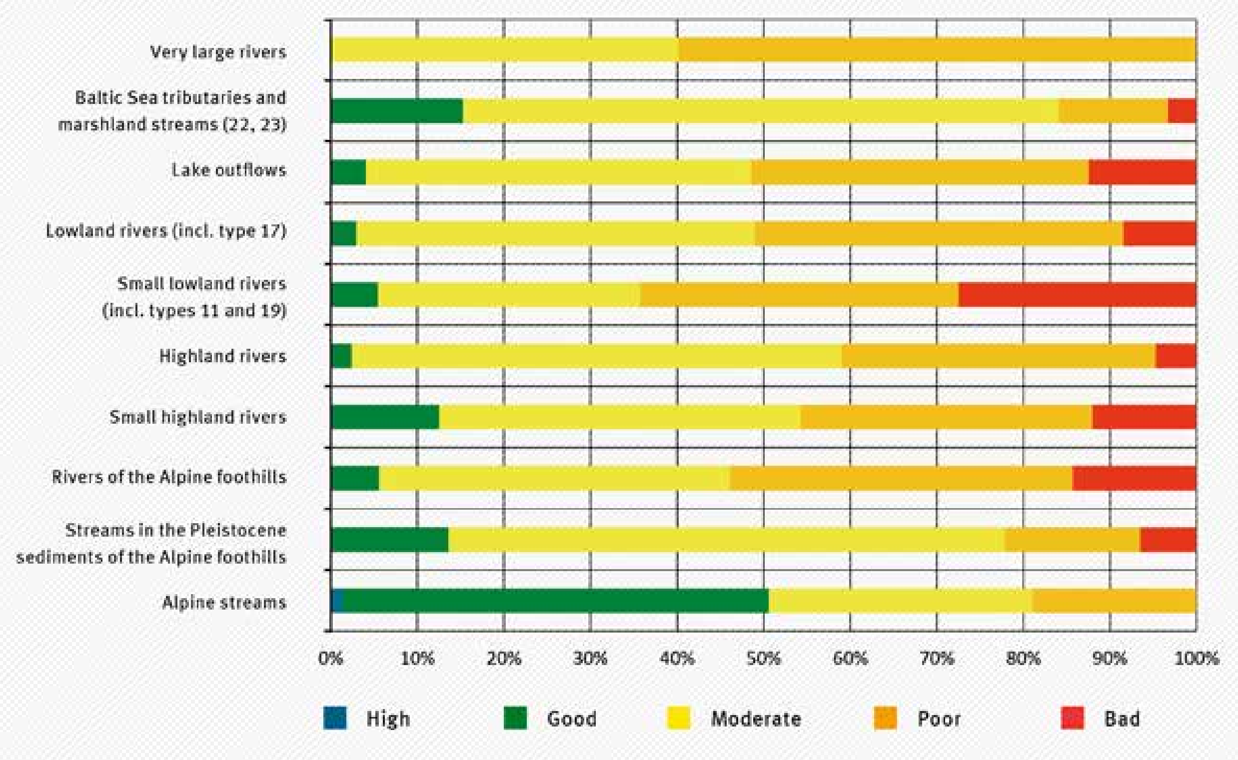
Ecological status of natural water bodies and ecological potential of heavily modified and artificial water bodies in Germany



Source: German Environment Agency after LAWA 2016b

Figure 10

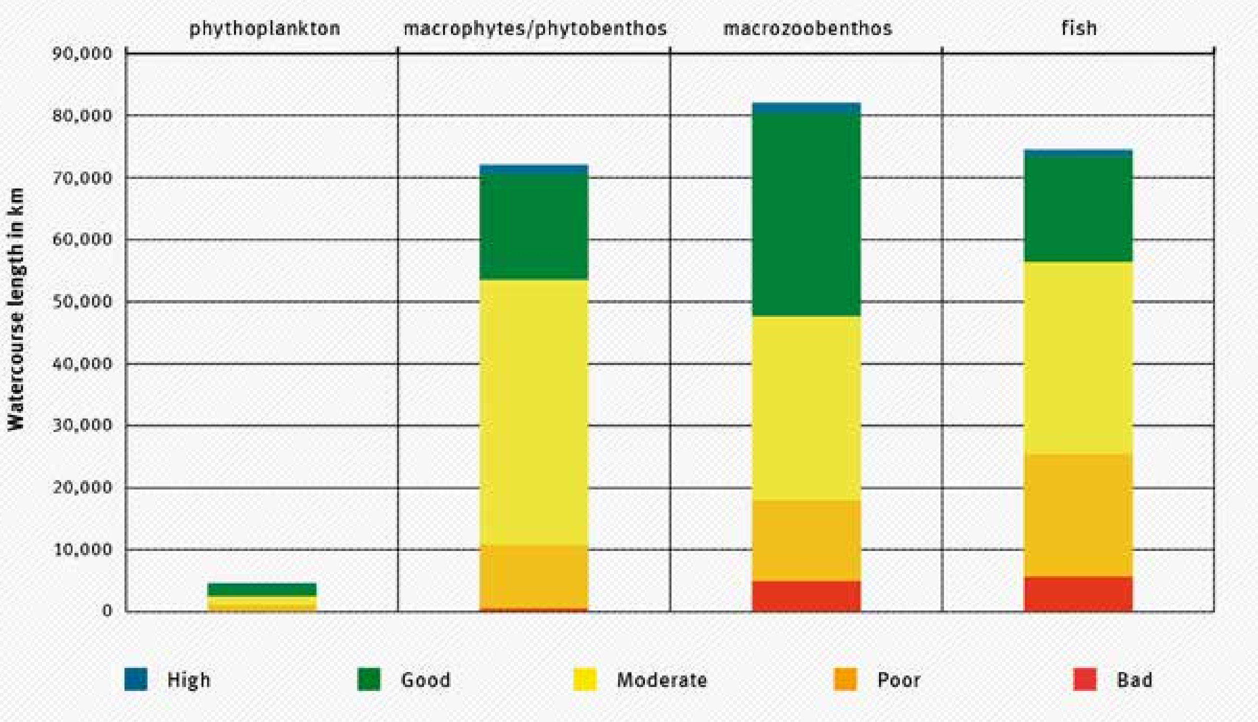
Percentage distribution of ecological status classes among natural water bodies according to stream and river-type



Source: German Environment Agency after LAWA 2016b

Figure 12

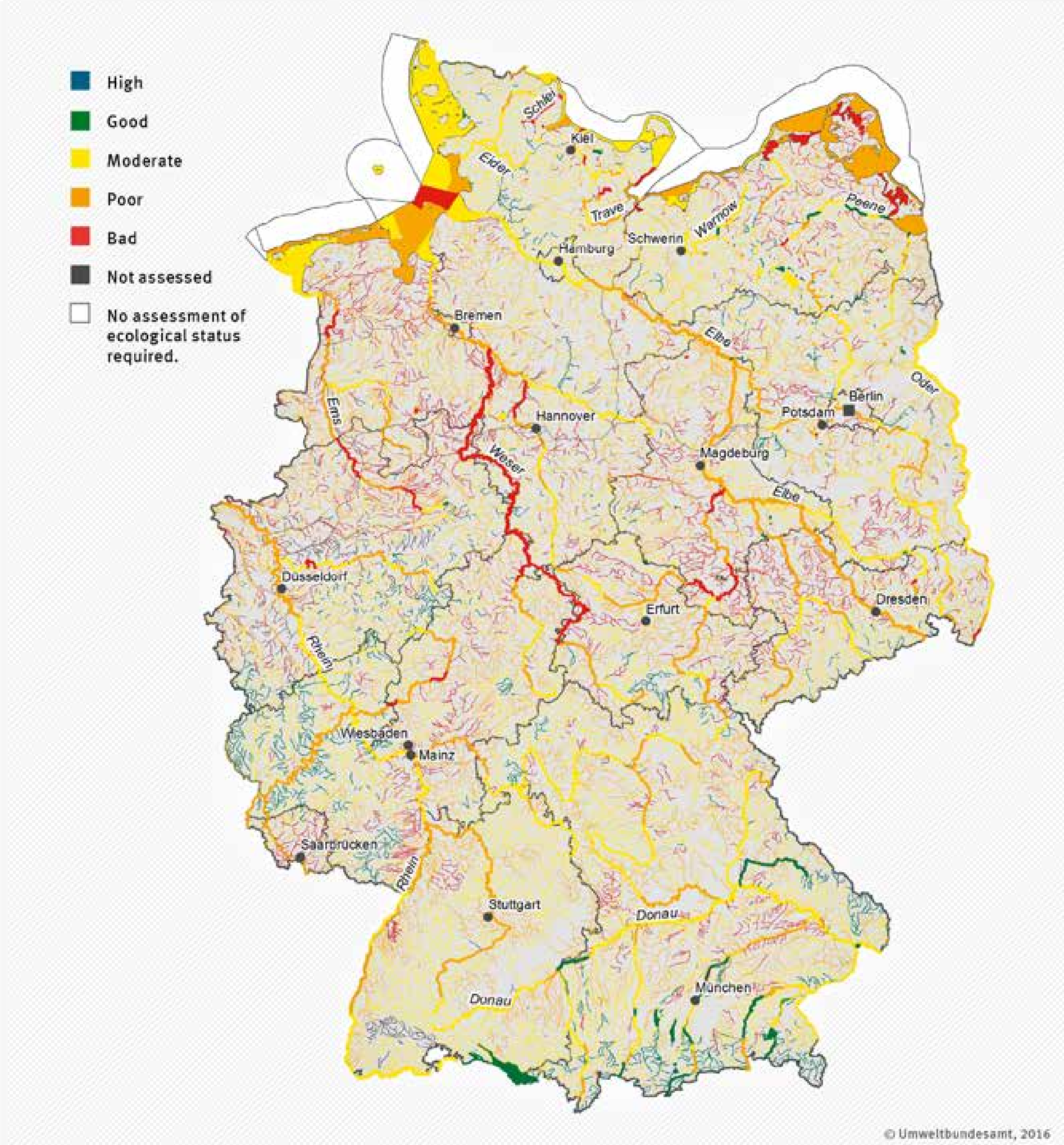
Ecological status of biological quality elements in Germany's natural water bodies



Source: German Environment Agency after LAWA 2016b

Figure 11

Ecological status/ecological potential of surface water bodies in Germany

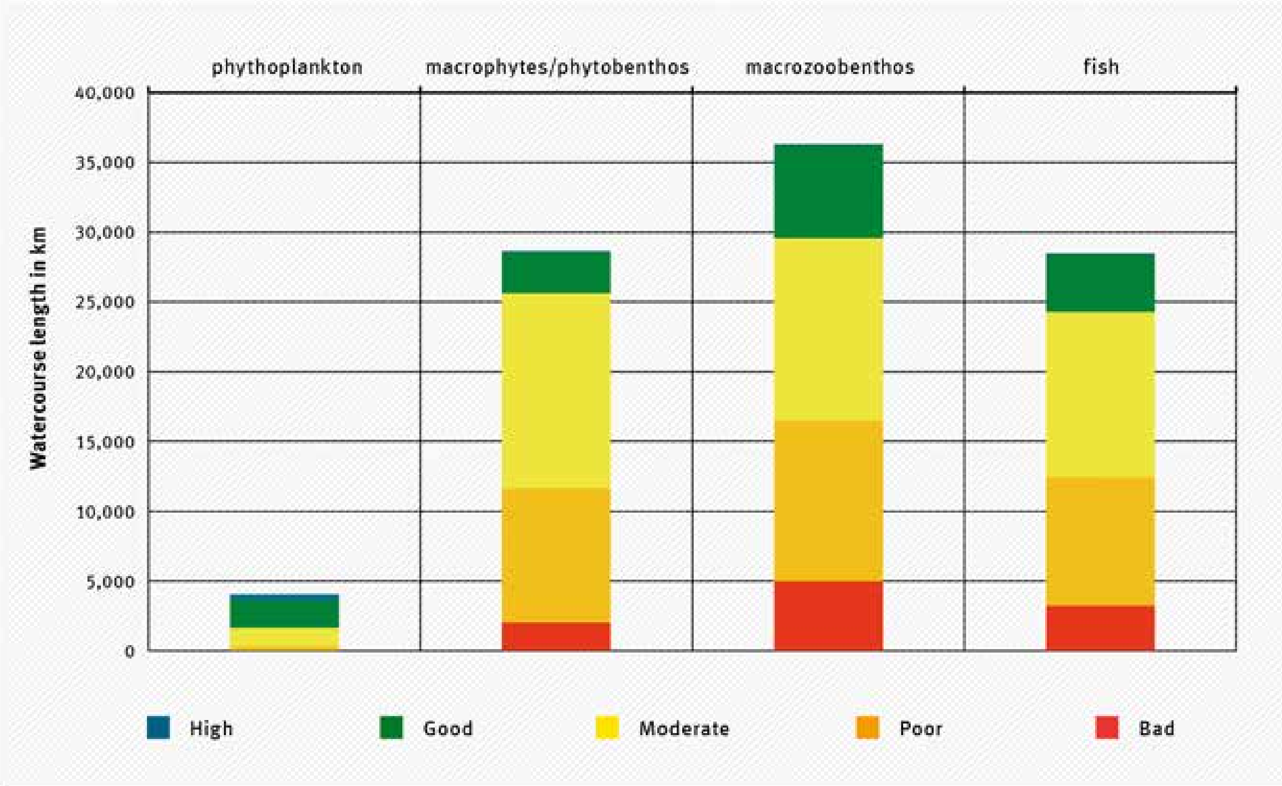


Source: Geobasis data: GeoBasis-DE/BKG 2015, professional data: LAWA 2016b, edited by: German Environment Agency, German Working Group on water issues of the Laender and the Federal Government (LAWA)

Not all quality elements were assessed in every case (see chapter 4.3). Macroinvertebrates were assessed on 98 % of the length of all natural watercourses, while macrophytes / phytobenthos and fish were only assessed on 91 % and 89 % respectively. Phytoplankton is only monitored in very large rivers (5 % of total stream and river length) (Figure 12). Applying the assessment principle whereby "the worst assessment of an individual biological quality element determines the overall status" (one out – all out) has a decisive influence on the assessment of overall ecological status. Whereas only 9 % of the watercourse length of natural streams and rivers achieves a status of "good" or above, individual biological quality elements are assessed as "good" or above far more frequently. This is true for phytoplankton (45 %), macroinvertebrates (42 %), macrophytes/phytobenthos (27 %) and fish fauna (24 %) in relation to the watercourse length of streams and rivers being assessed.

Figure 13

Ecological potential of biological quality elements in heavily modified water bodies (HMWB) in Germany



Source: German Environment Agency after LAWA 2016b

The differences in the sensitivity of the various biological quality elements to various pressures, and application of the "one out all out" principle, should ensure that all relevant pressures in a given water body are taken into account when planning measures (LAWA 2016b).

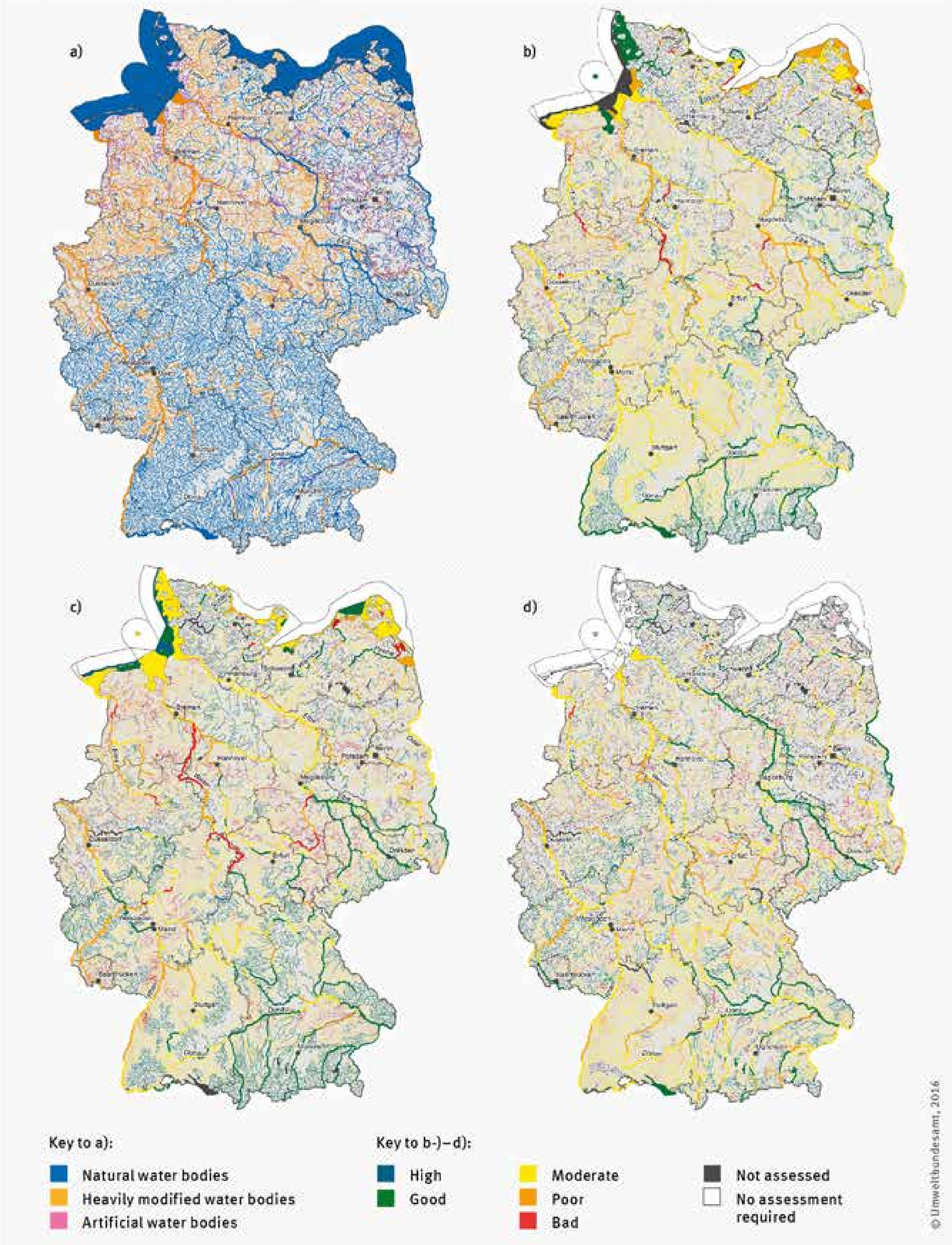
Application of the "one out all out" principle has comparable effects when assessing ecological potential. Among heavily modified water bodies, the proportion of watercourse length with a good (or above) ecological potential for macrophytes / phytobenthos, macrozoobenthos and fish fauna is generally low (Figure 13) – just under 12 % for macrophytes / phytobenthos, just over 19 % for macroinvertebrates, and 15 % for fish fauna. Despite this, as with natural water bodies, the assessments of these quality elements are significantly higher than the overall assessment of ecological potential (2 % good or above). Around 13,100 km (34 %) of all HMWB were classified as "moderate". The proportion of watercourse length with a "poor" ecological potential was around 41 % (15,000 km), while around 8,600 km (22 %) were classed as "bad". 2 % of the watercourse length in HMWBs was not assessed (LAWA 2016b).

Among artificial bodies of surface water, the assessment result is as follows: around 5 % (630 km) was classified as "good", 35 % (4,500 km) as "moderate", around 4,800 km (38 %) as "poor" and 2,800 km (22 %) as "bad" (see Figure 9). 5 % of the length of artificial watercourses was not assessed, including the Mittelland Canal, the Dortmund-Ems Canal and the Elbe-Havel Canal (LAWA 2016b).

The differences between the individual biological quality elements in terms of the proportions of watercourse length assessed as good or above, which are significantly higher among natural water bodies than among HMWBs and artificial water bodies, are often attributable to existing differences in land use intensity along the height gradient from the mountains to the lowlands, which is also reflected in the regional frequency of water bodies designated as HMWBs and natural (Figure 14a). In other words: the proportion of HMWBs and artificial water bodies is higher in the lowlands than in the mountains.

Figure 14

a) Natural, heavily modified and artificial water bodies
b) Ecological status/potential – Macrophytes/phytobenthos
c) Ecological status/potential – Macrozoobenthos
d) Ecological status/potential – Fish



Source: Geobasis data: GeoBasis-DE/BKG 2015, professional data: LAWA 2016b, edited by: German Environment Agency, German Working Group on water issues of the Laender and the Federal Government (LAWA)

5.2.2 Hydromorphology

The morphology, hydrological regime and continuity of watercourses are closely interrelated. Hydrological changes, interruptions to the river continuum and interventions into the morphological conditions influence the sediment regime. The erosion, relocation and depositing of bed materials is then no longer balanced, and the transportation of sediment loses its natural dynamic. This prevents landscape-shaping relocations of sand, gravel and scree, as well as woody debris, in weirs and water abstraction sections, and causes the disappearance or non-renewal of typical watercourse bed structures. Sediment retention in reservoirs and the prevention of side erosion lead to a lack of coarser material in the lower reaches. The river is only able to compensate for this deficit of sediments by gathering material from the bottom, causing it to "dig into" the landscape more extensively along certain sections. As a result, the groundwater level in the floodplains drops, and the hydrological regime is disturbed.

Quality element "morphology"

Apart from nutrient and pollutant levels, hydromorphological degradation of the watercourses, which occurs nationwide from the smallest stream to very large rivers, is largely responsible for only very few watercourse sections meeting the aspired ecological objectives (see chapter 5.2.1). The competent water management authorities in the German Laender have recorded the structures of watercourses, their shore zones and riparian areas over some 76,000 watercourse kilometres, and categorised them into 7 structural classes (Figure 15, see also morphological structure map https://www.umweltbundesamt.de/themen/wasser/fluesse/zustand (LAWA 2002)).

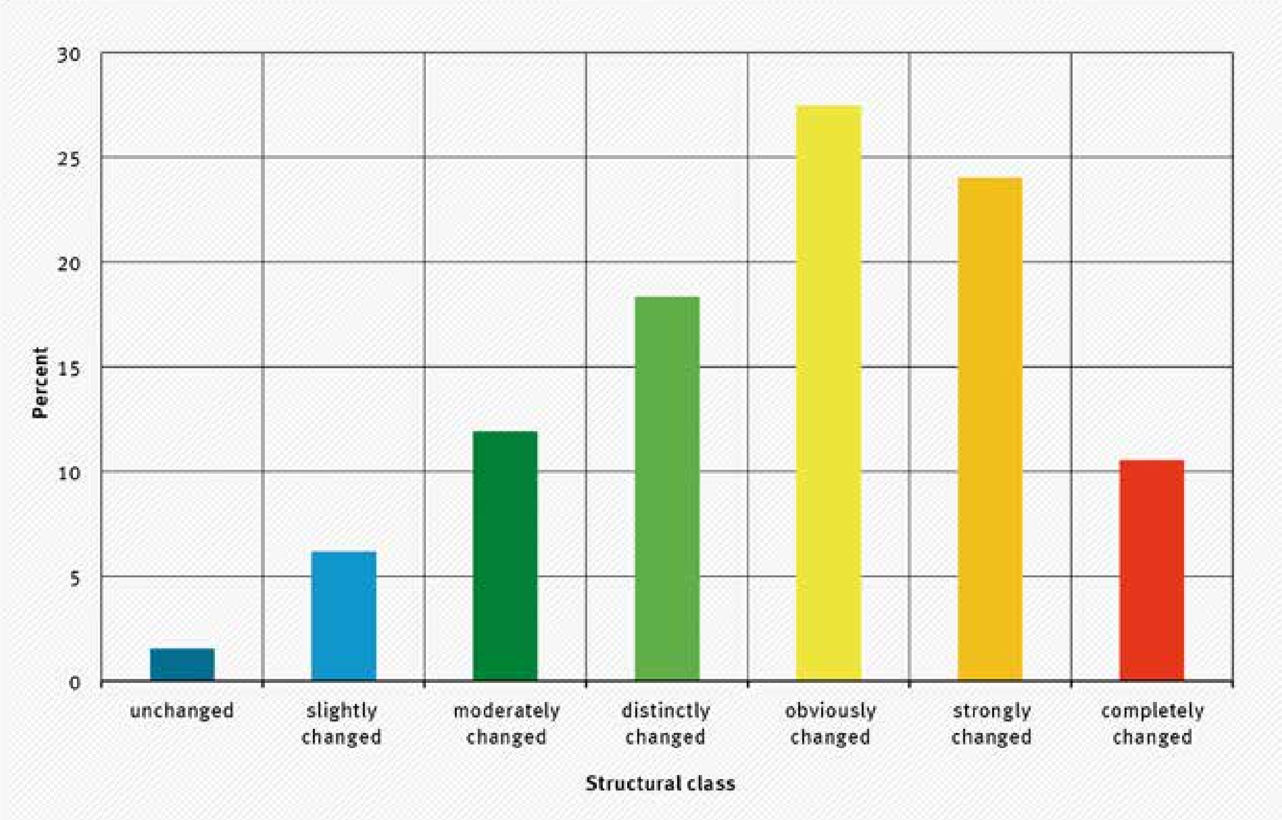
According to their findings, only 1,200 km (1.6 %) of the mapped watercourse sections remain unchanged and are therefore classed as completely natural. A further 13,800 km are only slightly or moderately changed and have been categorised in classes 2 and 2 (6.2 % slightly changed, 11.9 % moderately changed). Unchanged to moderately changed sections of streams and rivers can still be found in the Alps and pre-Alpine regions, in the granite and gneiss landscapes of the Bavarian Forest, in the upper reaches of the Central German Uplands, in the heathland landscapes of the North German lowlands and in the landscapes of Mecklenburg-Western Pomerania that were shaped by the ice age. In very small parts of these landscapes, river engineering measures and the melioration of the surrounding land is largely absent.

Small highland river close to the source
Source: Stephan Naumann

Gravel bank in the Mulde near Dessau
Source: Stephan Naumann

Figure 15

Result of the seven-point structure map for Germany using LAWA on-site and LAWA overview methods (last updated: 2014). Based on a watercourse length of: 76,097.4 km.



Source: Data compiled by the German Environment Agency following Datenrecherche 2014

Koblenz barrage weir in the Moselle; urban development, transport infrastructure, hydropower use and navigation determine river engineering measures
Source: Stephan Naumann

Near-natural small highland river
Source: Stephan Naumann
Small highland river close to the source

River in the Central German Highlands developed for flood protection
Source: Stephan Naumann

The vast majority – more than 60,000 km – of our rivers are "strongly" to "completely changed" and are classified in structural categories 4 to 7 (18.3 % "distinctly", 27.4 % "strongly", 24.0 % "very strongly" and 10.5 % "completely changed"). These include mid-sized rivers in the Central German Highlands, downlands and lowlands, which in the past were developed for the purposes of hydropower, flood protection or agricultural use.

Most large, heavily impaired rivers have been impounded and modified with weirs and locks for the benefit of navigation and hydropower use. Large parts of their flood plains have also been separated from the river and restricted by dykes to accommodate urbanisation, agricultural use and flood protection. For example, the development of the Upper Rhine resulted in a river bed up to 12 km wide giving way to a channel between 200 and 250 m wide; the Rhine floodplains between Basel and Karlsruhe decreased by 87 %. Overall, the natural floodplain area of the Upper Rhine was reduced by 60 % or 130 km², which in turn necessitated considerable expenditure to counteract the increased risk of flooding in downstream areas. All major rivers in Germany are in a similar situation. The BfN's report on floodplain status estimates that only 10–20 % of the former floodplains on major rivers are now available to retain flooding. Only 10 % of the floodplains analysed in river basins of > 1,000 km² can be described as "slightly" or "moderately changed" (BMU and BfN 2009). For this reason, the very large rivers have considerable structural deficits, and most of them are therefore classified as "distinctly changed" to "completely changed". This underscores the particular significance of near-natural sections of water on the large rivers, such as the free-flowing Danube above and below the mouth of the Isar.

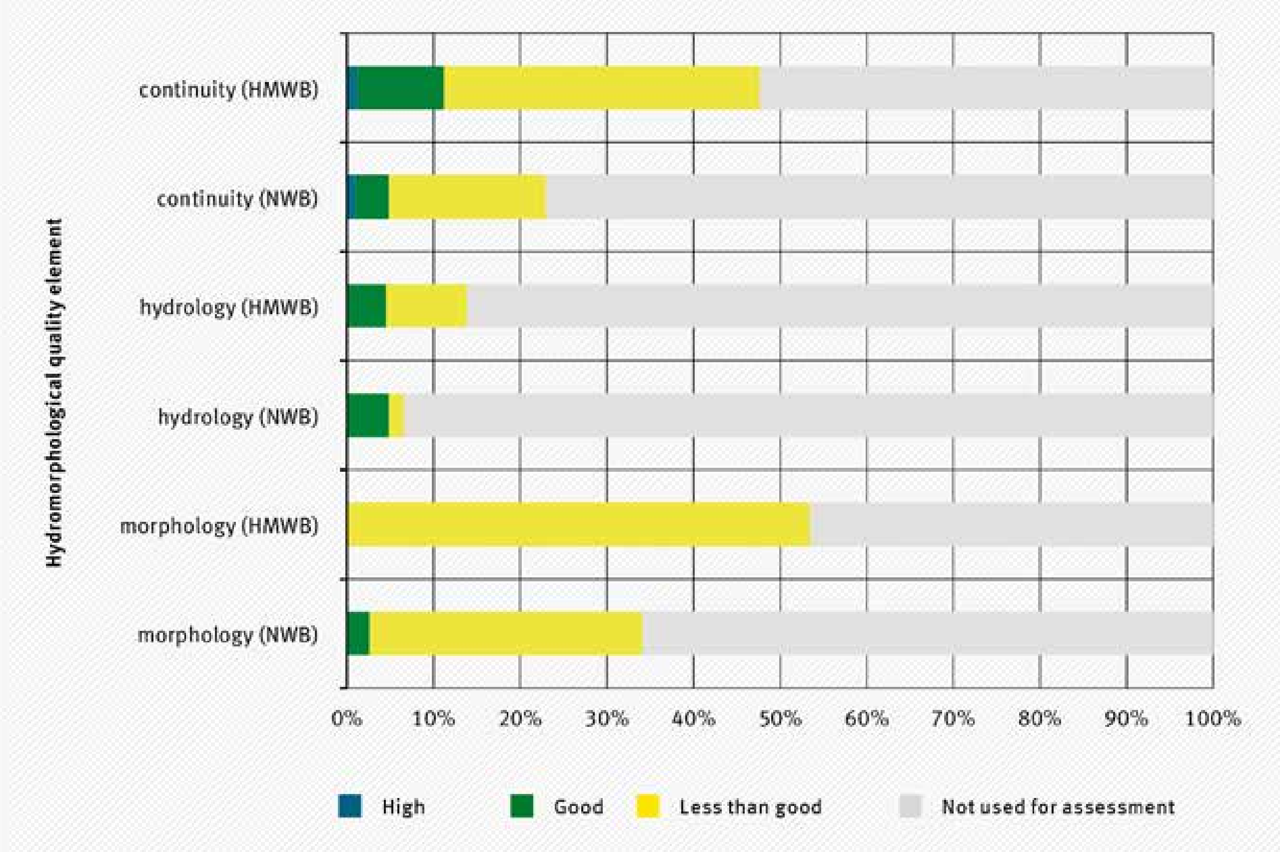
Designation as a "heavily modified" water body is another indication of high usage intensity in rivers and the associated hydromorphological impairments. In Germany, this affects 29 % of the watercourse length of rivers. Heavily modified water bodies (HMWB) occur primarily in the lowlands. Among sand- and gravel-dominated large rivers, only the Elbe, Oder and sections of the Danube are not classed as heavily modified water bodies (Figure 14a).

In order to report on implementation of the WFD to the European Commission, the quality element "morphology" was assessed for around 28,600 km, or 34 %, of natural watercourses (LAWA 2016b). This found that only 7 % of natural watercourse sections are in a state that would permit type-specific biological colonisation (Figure 16). The proportion of heavily modified water body sections in a good morphological status is tiny. Generally speaking, heavily modified water body sections, where they were assessed, were classified as worse than "good" (Figure 16).

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Figure 16

Classification status of the hydromorphological quality elements morphology, hydrology and continuity among natural (NWB – 83,800 km) and heavily modified (HMWB – 39,200 km) water bodies sections in Germany



Source: German Environment Agency after LAWA 2016b

Small highland river close to the source
Source: Stephan Naumann

Quality element "hydrology"
Until now, this method for classifying hydrology has only been used for selected examples and is still in the trial phase (Figure 16). To date, 7 % of natural and 14 % of heavily modified watercourses have undergone hydrological assessment, revealing that 74 % of natural and 32 % of heavily modified sections were assessed as "good" or above (LAWA 16b). However, it remains to be seen what the results will be following a complete classification of polluted sections.

Quality element "continuity"
A watercourse that has been left in its natural state is generally freely passable to migrating aquatic organisms in an upstream and downstream direction, but also perpendicular to the flow into the adjacent floodplains, and solid and dissolved matter is transported unhindered following the gradient. This is known as river continuity.

The continuity of Germany's watercourses is interrupted roughly every second kilometre by a technical structure. These transverse structures are used for drinking water abstraction, irrigation, hydropower use, navigation, bank support or the creation of artificial reservoirs for recreational purposes. There are thought to be some 200,000 transverse structures over the entire length of Germany's network of watercourses of more than 500,000 km.

A uniform nationwide classification method for continuity is due to become available for the 3rd management cycle. The relevant Laender authorities currently use their own assessment methods for reporting under the WFD (Figure 16), and statements have been made on the continuity quality of 23 % of natural and 48 % of heavily modified watercourse sections. In relation to these sub-sections, continuity is classed as good or above in 21 % of natural and 23 % of HMWB sections (LAWA 16b).

Within the context of the German Laender Initiative on Core Indicators (LIKI), continuity is regularly assessed by the Laender using the fish passability indicator. The indicator is defined as the proportion of transverse structures that are passable to fish versus the total number of transverse structures in water bodies with catchment areas of more than 100 km². Potamodromous and diadromous fish species migrate in fresh water and cover large distances between fresh water and seawater during their lifecycle. At present, some 49 % of all assessed, significant transverse structures in the migration routes of these species are passable in an upstream direction. In these particularly significant water bodies, the aim should be to ensure the passability of all transverse structures for fish wherever possible.

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

A classification approach for sediment passability is currently under development (Keuneke, R. and Donner, M. 2016). Examples of the consequences of a lack of sediment passability include the Rhine, which has deepened by up to 7 m, the Isar (up to 8 m) and the Elbe (up to 1.7 m), and the trend towards further deepening is continuing. The majority of rivers in Germany are thought to exhibit an unnaturally high level of depth erosion. This process is often masked and displaced downstream by the retrospective installation of transverse structures to reinforce the river bed. As a result, the river breaks its banks less frequently, and the groundwater level in the adjacent floodplain falls. The naturally linked ecosystems of the river and floodplains are disconnected.

Fish ladder on the Koblenz barrage weir on the Moselle
Source:Stephan Naumann

5.2.3 Nutrients

Total phosphorus and nitrogen inputs into Germany's surface waters have been substantially reduced, thanks to the introduction of phosphate-free detergents, the closure of production facilities, the construction and modernisation of municipal and industrial wastewater treatment plants (phosphate precipitation plants), and the greater number of households connected to wastewater treatment facilities. Today, agriculture is the principal source of nutrient loads in surface waters, while municipal wastewater treatment plants, power plants, transport and industrial operations are also contributors.

Coarse-sand sediment in Buhnenfeld on the Elbe near Dessau
Source: Stephan Naumann

Nutrient pathways in Germany are calculated, inter alia, using the MoRE (Modelling of Regionalized Emissions) model (Fuchs et al. 2017). The latest results from this model are outlined below. In 2012–2014, nitrogen inputs into Germany's surface waters totalled 487,800 t/a, a decrease of around 50 % compared with the period 1983–1987 (over 1 million tonnes per annum) (Figures 17, 48, 61). This is primarily due to the decrease in nitrogen inputs from point sources (municipal wastewater treatment plants and direct industrial dischargers) thanks to the improved purification performance of wastewater treatment plants, which accounted for 19 % of total inputs (2012–2014). Nitrogen inputs from diffuse sources decreased by 35 %. 51 % of nitrogen entered surface waters via the groundwater in 2012–2014. Nitrogen inputs from agriculture therefore dominate, accounting for around 75 % of nitrogen inputs into surface waters.

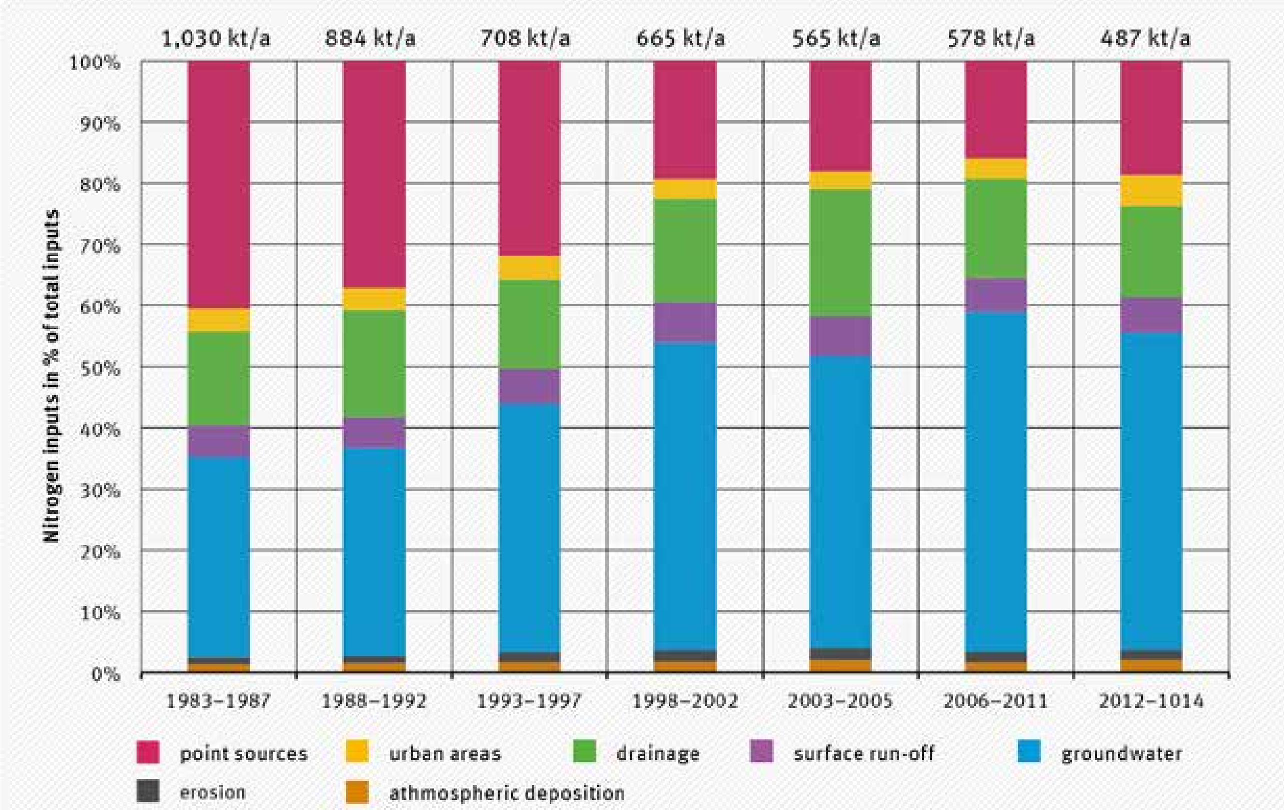
Phosphorus inputs into Germany's surface waters totalled around 23,000 t/a in 2012–2014 (Figures 18, 49, 62), a reduction of around 59,000 t/a or 72 % compared with the period 1983–1987. This too is primarily attributable to the reduction in inputs from point sources (87 %). Despite this, point sources still accounted for 34 % of total inputs in 2012–2014. Overall, diffuse phosphorus inputs have only decreased by 29 % in the last 20 years. The reduction of inputs from urban areas (combined sewer overflows and rainwater discharges, residents not connected to a municipal wastewater treatment plant or sewer system) accounted for the bulk of the reduction in diffuse inputs. Among diffuse sources of phosphorus, inputs via the groundwater account for 21 % of total inputs, followed by inputs via erosion at 16 %. Phosphorus inputs from agriculture account for around 50 % of total phosphorus inputs.

The reduction in inputs is reflected in decreased concentration levels in rivers and streams. Concentrations of phosphorus and nitrogen compounds are influenced by flow rate. Flow rate numbers are not available for all monitoring sites, and therefore the measurement values cannot always be standardised to the flow rate. For hydrology, for example, values over ten years are combined into long-term series. This method is subsequently applied to the concentrations. The 90-percentile values for the three ten-year periods (1986–1995, 1996–2005 and 2006–2015) at LAWA monitoring sites for which data is available for at least five years are averaged out (Figure 19), so that changes in concentrations are less attributable to fluctuations in flow rate

Small highland river close to the source
Source: Stephan Naumann

Figure 17

Nitrogen inputs from point and diffuse sources into Germany's surface waters



Source: German Environment Agency (MoRE), as at: August 2016 and more to inputs. Comparing the first two ten-year periods 1986–1995 and 1996–2005 reveals a sharp drop in phosphorus and ammonium concentrations, both in terms of the intensity of the decrease and the number of monitoring sites. While this continued in the third period in the case of ammonium, the decrease in phosphorus concentrations tailed off, and at some monitoring sites even increased slightly, but remained below the concentrations of the first period. Concentrations of nitrate decreased more slowly.

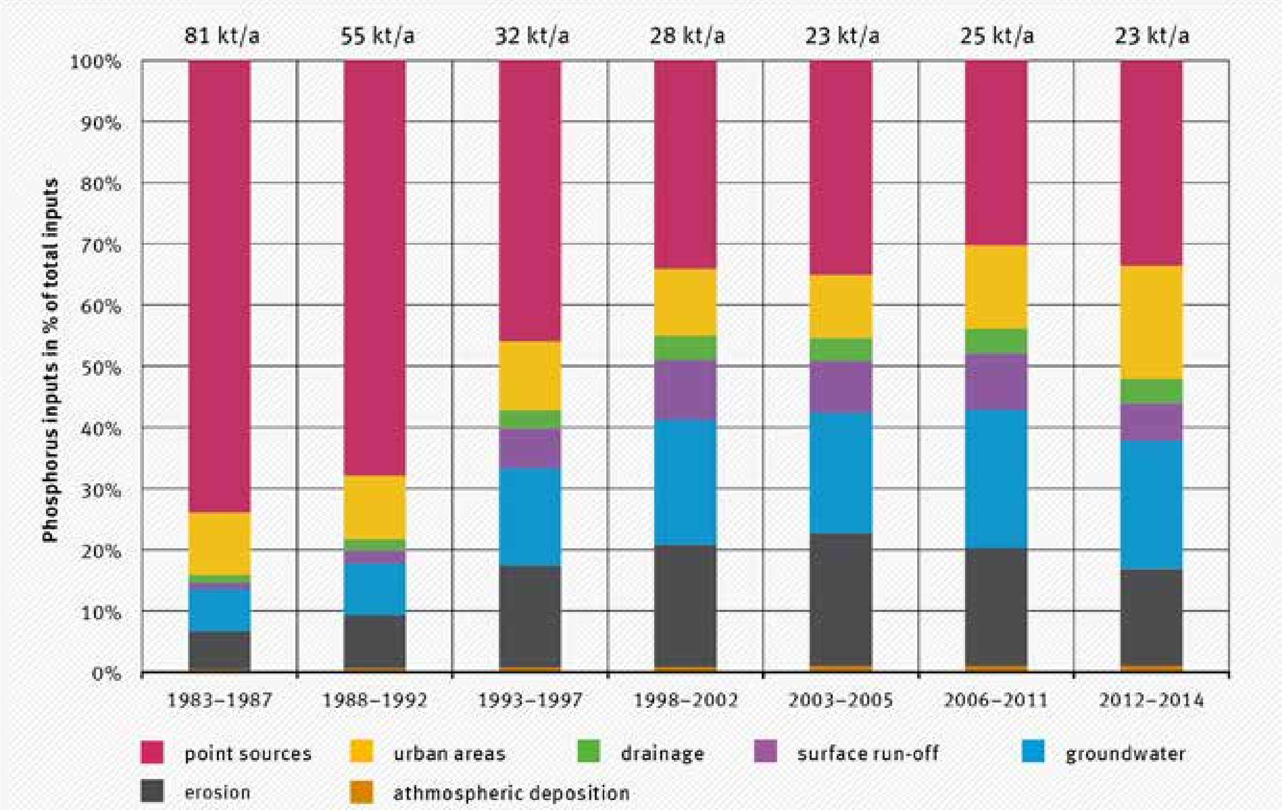
The distribution of monitoring sites among quality classes (see chapter 5.1.5) in the period 1982 to 2015 also reflects this decrease (Figures 20–22). Whereas concentrations of total phosphorus and ammonium nitrogen had already started to decrease in the early 1990s, the reduction in nitrate nitrogen did not take effect until the mid-1990s, and was not as pronounced as for total phosphorus and ammonia nitrogen.

Nevertheless, phosphorus and nitrogen concentrations still exceed a range that would allow them to achieve a good ecological status/potential in all areas (chapters 4.2.1, 5.1.4). In 2015, the threshold value was met by ammonium at 89 % of monitoring sites and by phosphorus at 30 % of monitoring sites. For nitrate, in addition to the "target value" of 2.5 mg N/l, there is also an action value of 50 mg NO3/l (see chapter 4.2.3, corresponds to 11.3 mg/l nitrate nitrogen). Although the action value was met by all LAWA monitoring sites in 2015, only 19 % of them reported nitrate nitrogen concentration levels below the "target value". Further assessments may be found on the website https://www.umweltbundesamt.de/themen/wasser/fluesse/zustand/naehrstoffe.

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Figure 18

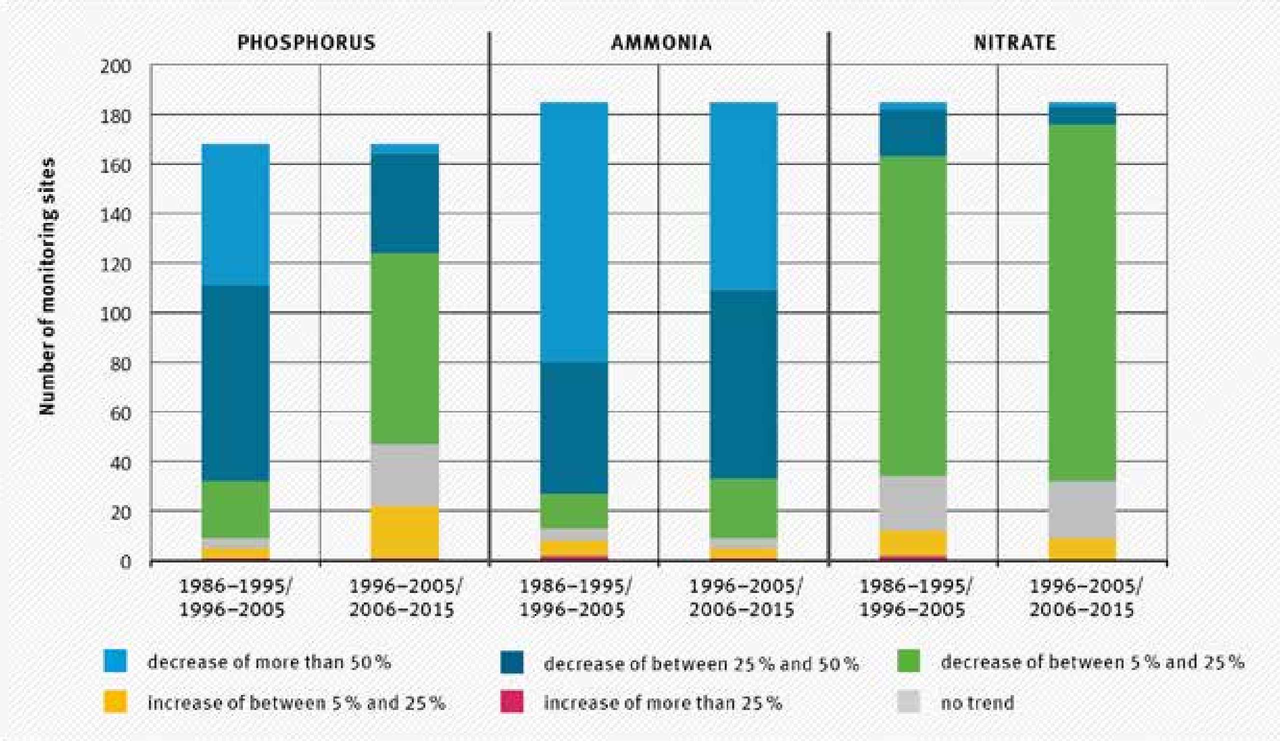
Phosphorus inputs from point and diffuse sources into Germany's surface waters



Source: German Environment Agency (MoRE), as at: August 2016

Figure 19

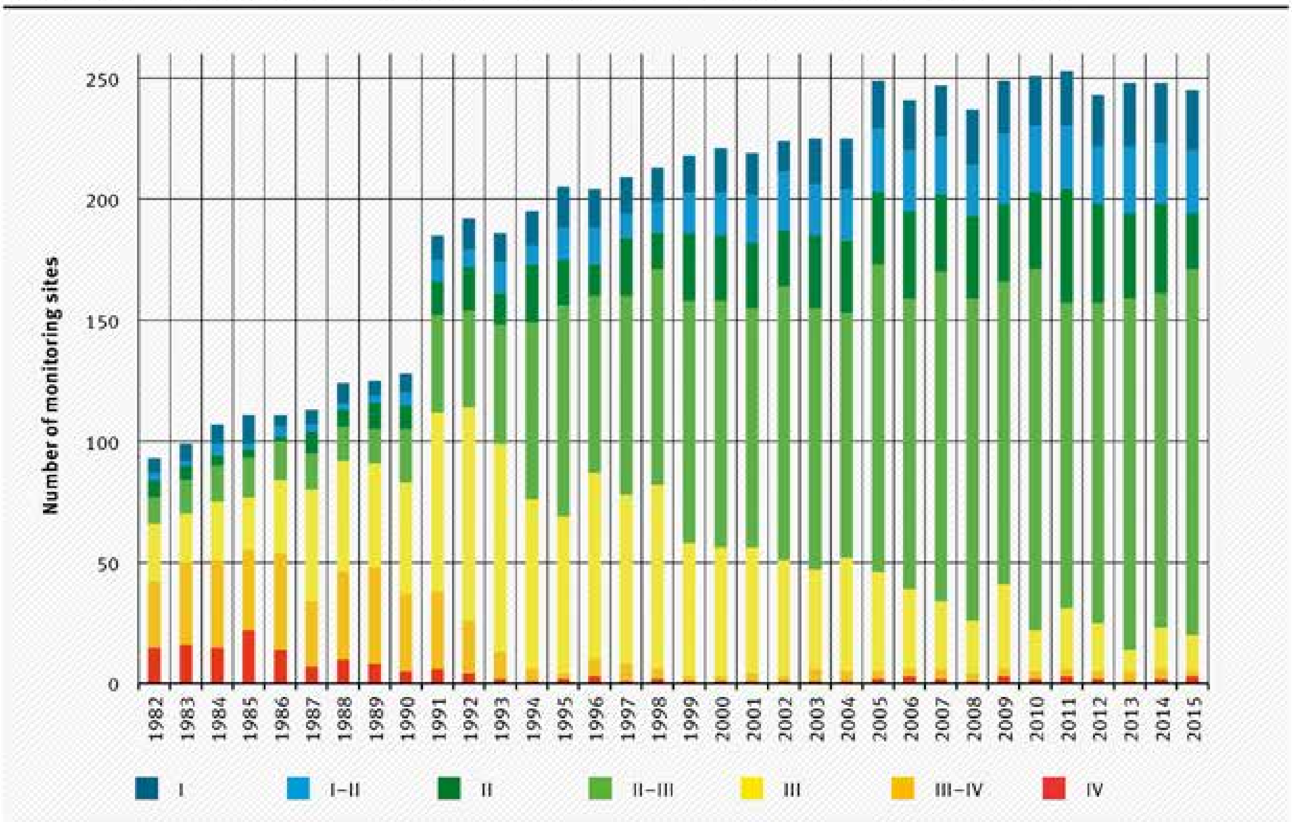
Change in concentration levels of total phosphorus, ammonia nitrogen and nitrate nitrogen, 1982–1995 versus 1996–2005 and 1996–2005 versus 2006–2015 (basis: LAWA monitoring network; mean 90-percentile for the years)



Source: German Environment Agency based on data supplied by LAWA

Figure 20

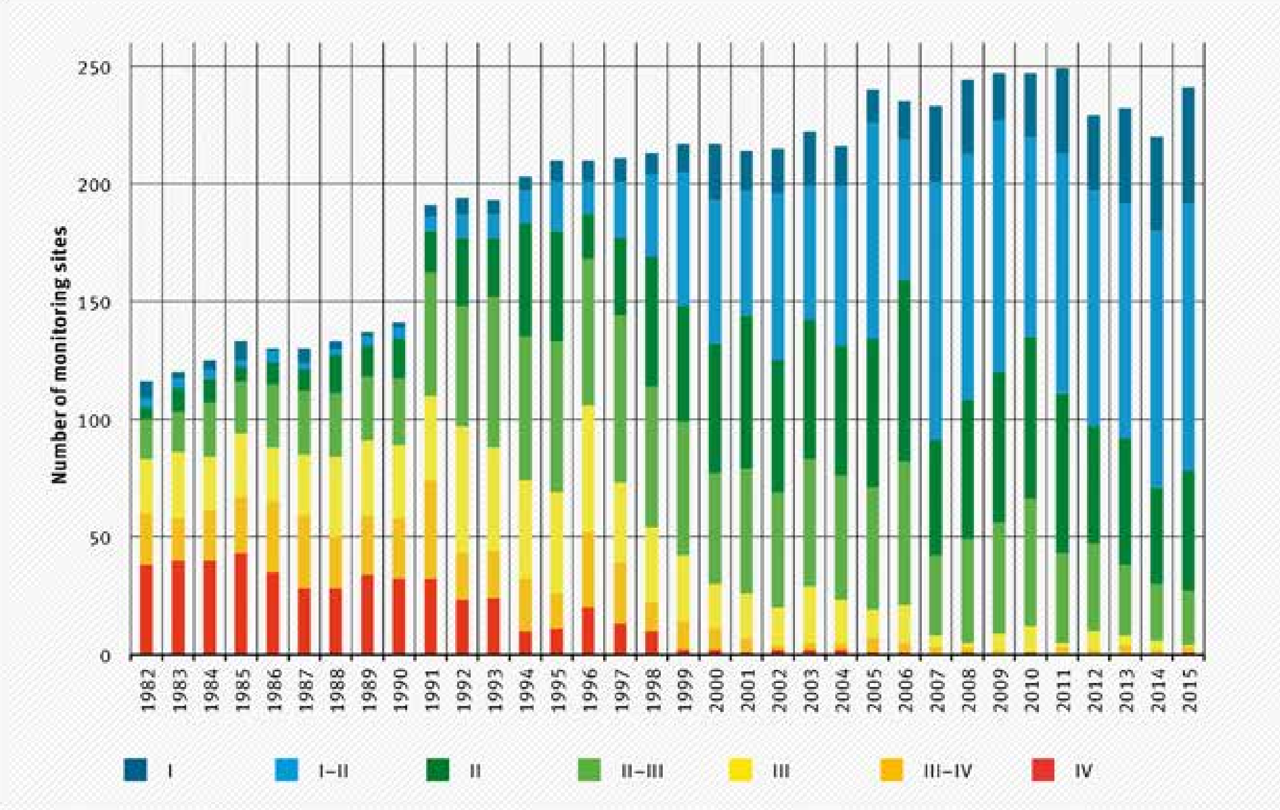
Quality classification for total phosphorus, 1982–2015 (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

Figure 21

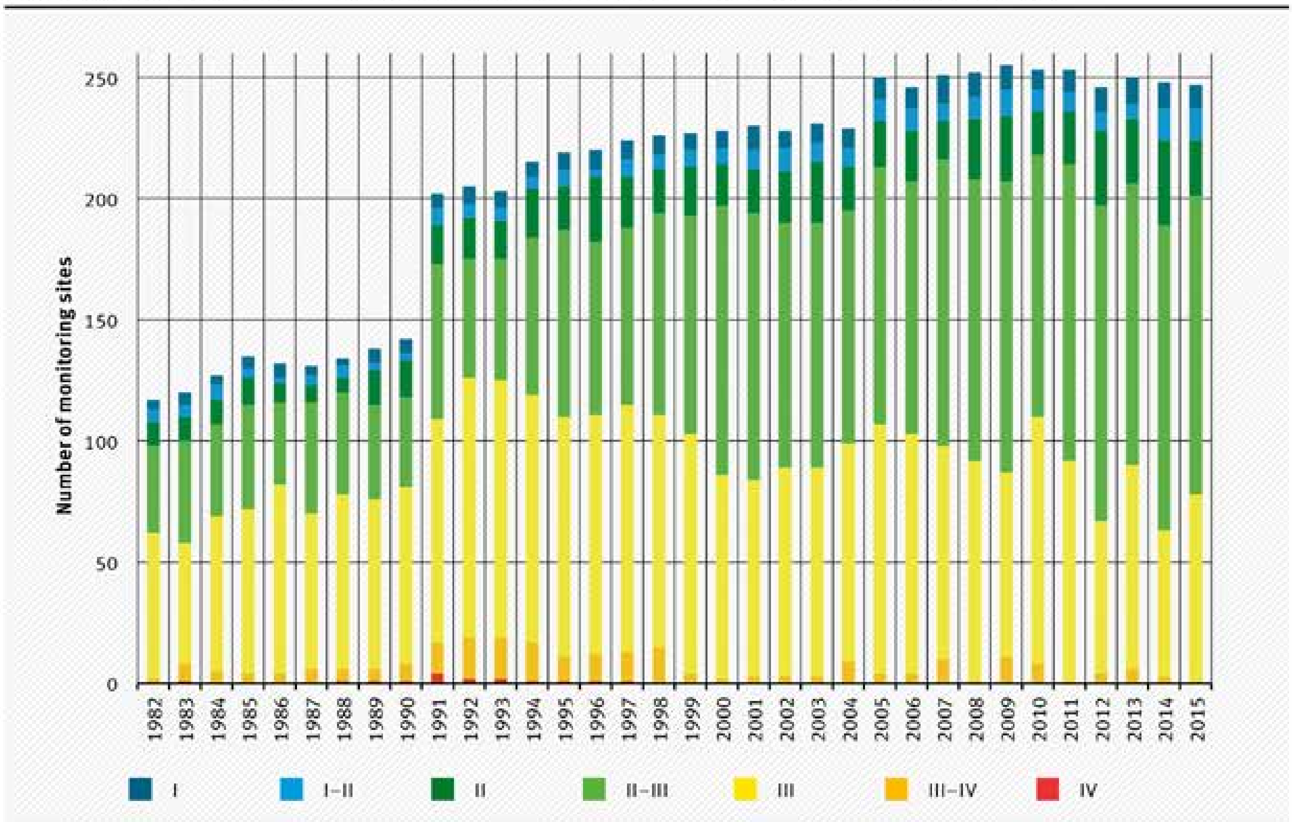
Quality classification for ammonium nitrogen, 1982–2015 (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

Figure 22

Quality classification for nitrate nitrogen, 1982–2015 (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

5.2.4 Heavy metals and metalloids

Inputs of metals into surface waters have been significantly reduced, thanks to the construction and modernisation of municipal and industrial wastewater treatment plants. For heavy metals, we have seen a dramatic reduction in industrial direct inputs (point sources), primarily thanks to statutory requirements in industry and the decrease in industrial production since 1990.

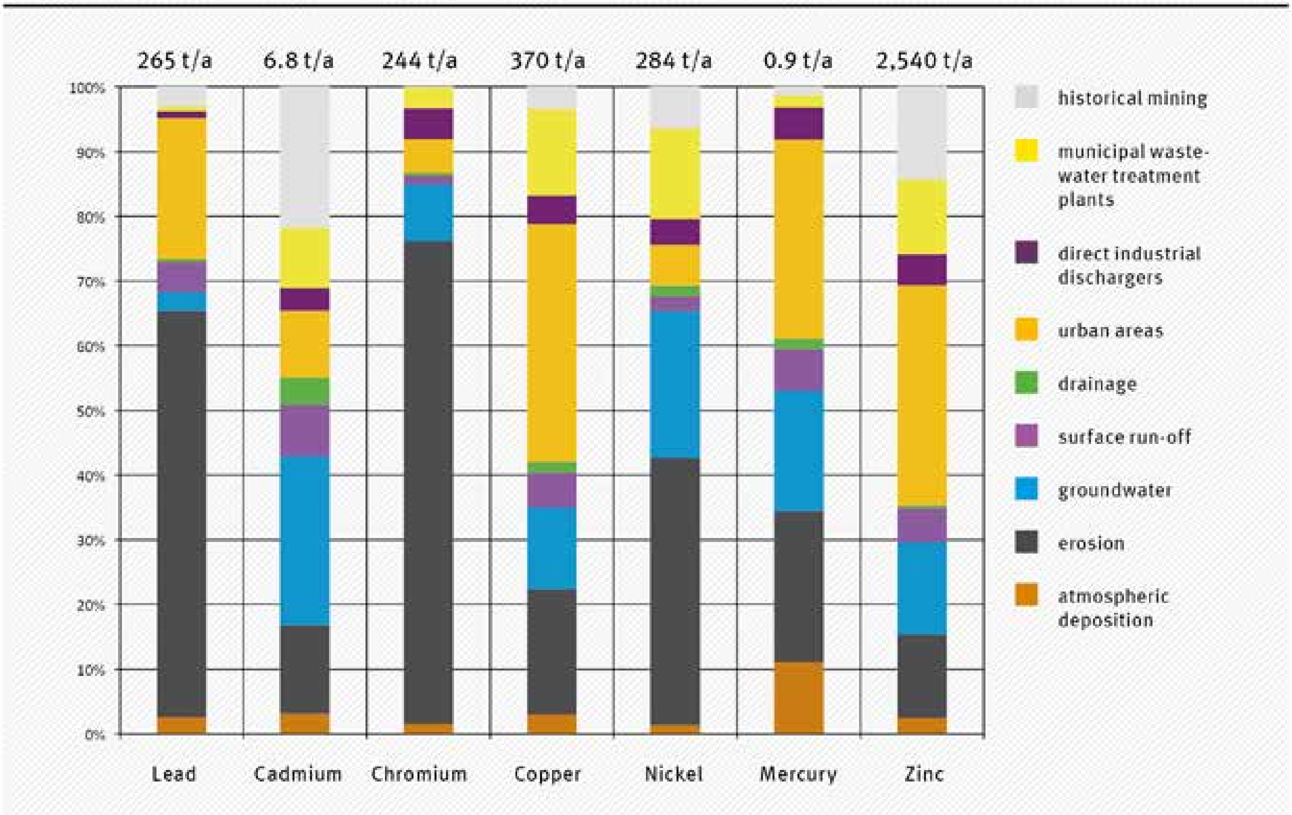
According to input modelling based on the MoRE model, direct industrial inputs played only a subordinate role in 2012–2014, ranging from 1 % (lead) to 5 % (mercury, zinc, chromium). Although inputs from municipal wastewater treatment plants remain high, in the years 2012–2014, once again, water pollution was dominated by inputs from diffuse sources, ranging from 65 % (cadmium) to 92 % (mercury, chromium). The principal diffuse pathways were erosion, groundwater and urban areas. In particular, chromium (74 %) and lead (62 %) are emitted into surface waters as a result of erosion. In the case of nickel (41 %), geogenic emission via the groundwater is the dominant pathway. With the exception of nickel and chromium, a high proportion of heavy metal inputs from surface waters also originates from urban areas, including inputs from combined sewer systems and rainwater discharges. Copper (37 %), zinc (33 %) and mercury (31 %) account for particularly high proportions of total inputs. As a significant portion of precipitation run-off is transported to the wastewater treatment plant in combined systems, the level of heavy metal water contamination from this source is lower than rainwater discharges for most heavy metals. In the case of zinc, cadmium, copper, nickel, lead and arsenic, historical mining (old tunnels) may also account for a high proportion of total inputs (Figure 23).

The assessment of metals is based on dissolved concentrations (lead, cadmium, nickel, mercury, selenium, silver, thallium), concentrations of suspended solids/sediment (arsenic, chromium, copper, zinc) and in biota (mercury) (cf. chapters 4.2.2 and 4.2.3). Whereas data for the assessment of suspended solids/sediment and dissolved concentrations is available from a large number of LAWA monitoring sites, measurements on biota (fish) for mercury and other pollutants have only been established in recent years at selected monitoring sites (see chapter 5.2.9). Measurements from the Environmental Specimen Bank (ESB) verify that mercury concentra-

Small highland river close to the source
Source: Stephan Naumann

Figure 23

Heavy metal inputs (lead, cadmium, chromium, copper, nickel, mercury, zinc) from point and diffuse sources into Germany's surface waters, 2012–2014



Source: German Environment Agency (MoRE), as at: September 2016 tion levels in fish have decreased sharply, particularly in the 1990s (see https://www.umweltprobenbank.de/en/documents). Initial measurements by the Laender on fish indicate that the environmental quality standard for mercury of 20 µg/kg, which was derived for the conservation of wild fauna that feed on fish, such as otters and fish eagles, is still exceeded almost everywhere. It is estimated that, alongside long-distance transportation, historical mercury deposits in water body sediments, for example in still water regions, are the principal cause.

In 2013–2015, the environmental quality standard for suspended solids/sediment was exceeded a number of times in the case of zinc, copper and arsenic. The environmental quality standards for dissolved concentrations was likewise exceeded at a number of monitoring sites in the case of nickel and cadmium (Figure 24). Whereas problems with arsenic and cadmium occur at monitoring sites with tunnels from mining legacies in the catchment area (such as Mulde), cases where the environmental quality standard for copper was ascertained were primarily downstream of conurbations (such as the mouth of the River Spree in Berlin). In the case of zinc, there are large cities or historical mining in the catchment area of the polluted monitoring sites. In the case of nickel, assessment was based on the dissolved concentration. If nickel concentrations are related to the bioavailable concentrations, the number of monitoring sites that exceed the annual average environmental quality standard (AA-EQS) is likely to be lower. No pollution hot-spots have been identified.

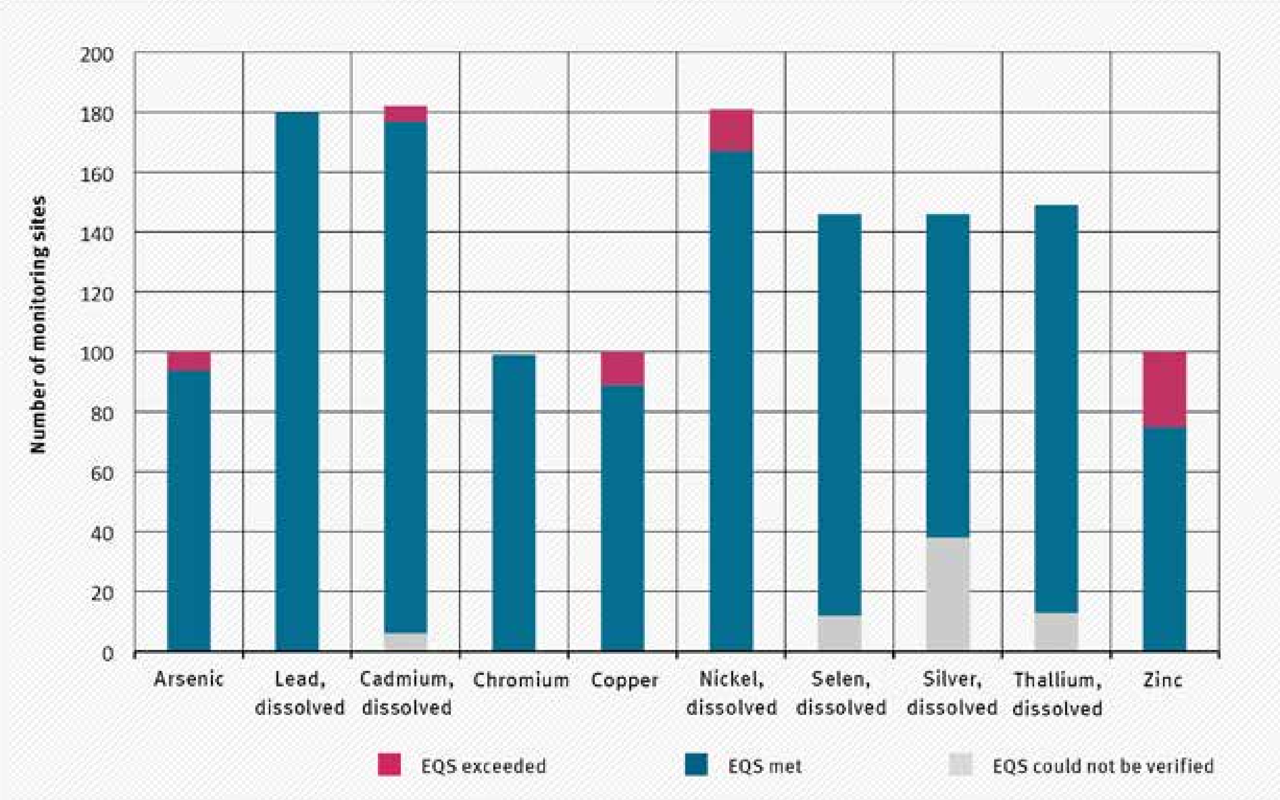
5.2.5 Industrial chemicals

Due to the good status of waste water treatment industrial chemicals are mainly emitted diffusely into surface waters. The high proportion of diffuse emissions is illustrated using the example of the polycyclic aromatic hydrocarbons (PAH – in this instance PAH_{16}). For the period 2012–2014 16,300 kg of PAH_{16} was emitted into surface waters in Germany, the bulk of it via urban areas (combined sewer overflows, rainwater discharges, and residents not connected to a municipal waste water treatment plant or sewer system), followed by atmospheric deposition on water body surfaces, inland shipping and erosion (Table 16).

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Figure 24

Comparison of annual means for 2013–2015 with the environmental quality standard for selected metals (dissolved concentration and suspended solids/sediment, LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

Table 16

PAH_{16} inputs into Germany's surface waters (2012–2014); values rounded

Emission pathways	Σ EPA-PAH_{16} [kg/a]
Atmospheric deposition	4,376
Erosion	1,200
Groundwater	135
Direct industrial dischargers	80
Inland shipping	1,360
Surface runoff	940
Drainage	10
Urban areas	7,350
Municipal wastewater treatment plants	970
Total	**16,300**

Source: German Environment Agency (MoRE), as at: August 2016

Eight of the PAH_{16} are subject to European-wide regulation (chapter 4.2.3). PAH concentrations of fluoranthene and benzo[a]pyrene are assessed in two ways: via the concentration in mussels (biota environmental quality standard (biota EQS)) and via the concentration in the total water sample (maximum admissible concentration (MAC-EQS)). In 2016, the Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency published analysis results for mussels taken from the Aller, Elbe, Ems, Vechte and Weser (NLWKN 2016). Concentrations of fluoranthene and benzo[a]pyrene are below the respective environmental quality standards. Comparisons of the maximum total concentrations with the MAC-EQS at LAWA monitoring sites also reveals pollution, particularly with benzo[g,h,i]perylene (Figure 25). For all other industrial chemicals in Tables 7 and 8, concentrations are below the environmental quality standards (see also Figure 28).

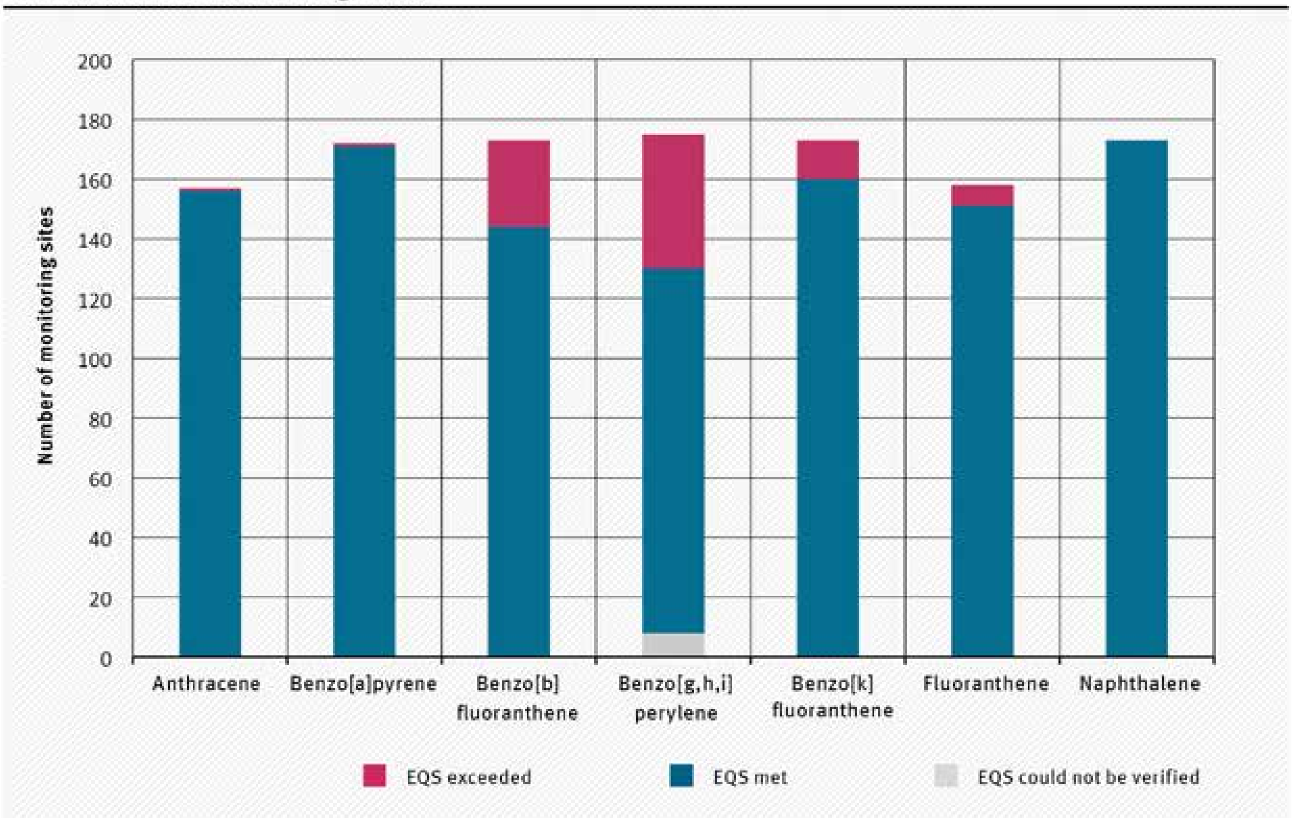
5.2.6 Pesticides

Pesticides and biocides are discharged into rivers and streams primarily via diffuse sources (such as leaching from agricultural land, leaching from house-painting). Of the 61 active substances regulated by the Ordinance on Surface Waters (see chapters 4.2.2 and 4.2.3) that are used in pesticides and/or biocides, 30 complied with environmental quality standards during the period 2013–2015. For a further 15 active substances, compliance with the environmental quality standard cannot always be verified because the limit of quantification

Small highland river close to the source
Source: Stephan Naumann

Figure 25

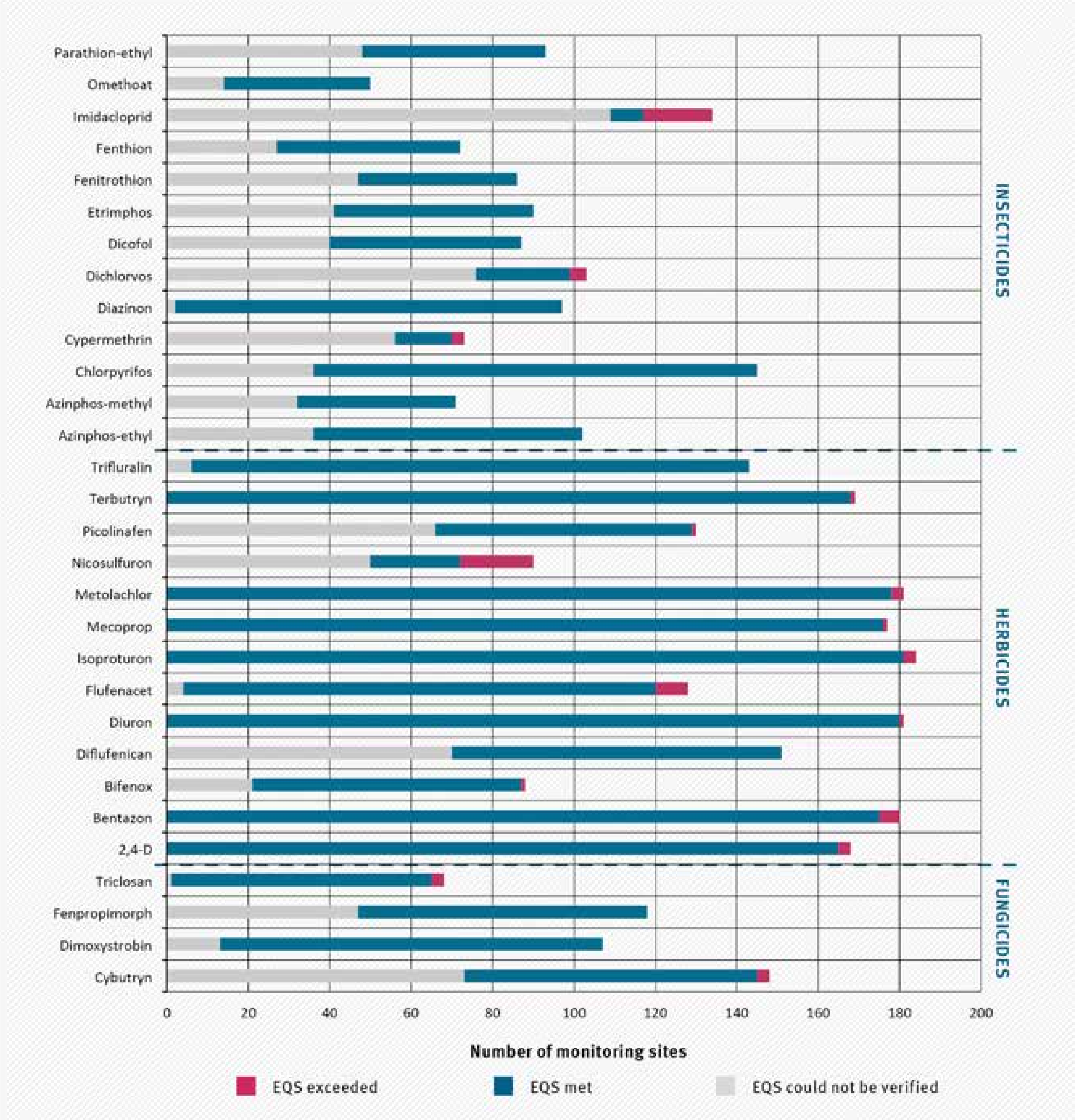
Comparison maximum in 2013–2015 with the maximum allowable concentration (MAC-EQS) for PAH (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

Figure 26

Comparison of annual means in 2013–2015 with the environmental quality standard for selected pesticides (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

exceeds the environmental quality standard (Figure 26). The EQS was found to be exceeded in the case of the active substances nicosulfuron, imidacloprid, flufenacet, bentazone, dichlorvos, 2,4-D, cybutryne, cypermethrin, isoproturon, metolachlor, triclosan, bifenox, diuron, mecoprop, picolinafen and terbutryn (in descending order of the number of monitoring sites where levels were exceeded).

5.2.7 Persistent organic pollutants under the Stockholm Convention

The Stockholm Convention calls for the discontinuation or restriction of the production, use and release of persistent organic pollutants (POP). In the EU, it has been translated into a directly valid EU Regulation (Regulation 850/2004/EC), and entails extensive reporting obligations for the Member States. Further explanatory information may be found on the website https://www.umweltbundesamt.de/themen/chemikalien/chemikalien-management/stockholm-konvention. 14 POPs are also regulated by the Ordinance on Surface Waters (see chapters 4.2.2 and 4.2.3).

For brominated diphenyl ether (BDE), heptachlor, hexabromocyclododecane (HBCDD), hexachlorobenzene (HCB), hexachlorobutadiene and perfluorooctane sulfonate (PFOS), the Ordinance on Surface Waters defines environmental quality standards both for the concentration of suspended solids/sediment (polychlorinated biphenyls (PCBs)) or in biota, and for the total water concentration. In such cases, measurements of suspended solids/sediment (PCB) or in biota should primarily be used for assessment purposes (chapters 4.2.2, 4.2.3). For biota, only a few measurements are available within the context of the Ordinance on Surface Waters (see chapter 5.2.8). The environmental quality standards for concentrations in total water samples of POP are either so low (AA-EQS) that the limit of quantification exceeds the environmental quality standard and therefore compliance cannot be verified; or else they are met (MAC-EQS).

Measurements of suspended solids/sediment are available for many monitoring sites. In the period 2013–2015, exceedances occurred for PCB101, PCB138, PCB153 and PCB180. The concentrations in the Elbe have risen again due to inputs from the renovation of a railway bridge in the Czech Republic.

For dioxins, an environmental quality standard has only been set for biota (see also chapter 5.2.8).

For POPs where environmental quality standards only exist for the total water concentration, these are met in the case of the cyclodiene pesticides (drines), endosulphane, pentachlorophenol and total DDT, but exceeded at a small number of monitoring sites in the case of hexachlorocyclohexane (HCH) and 4,4-DDT (Figure 28).

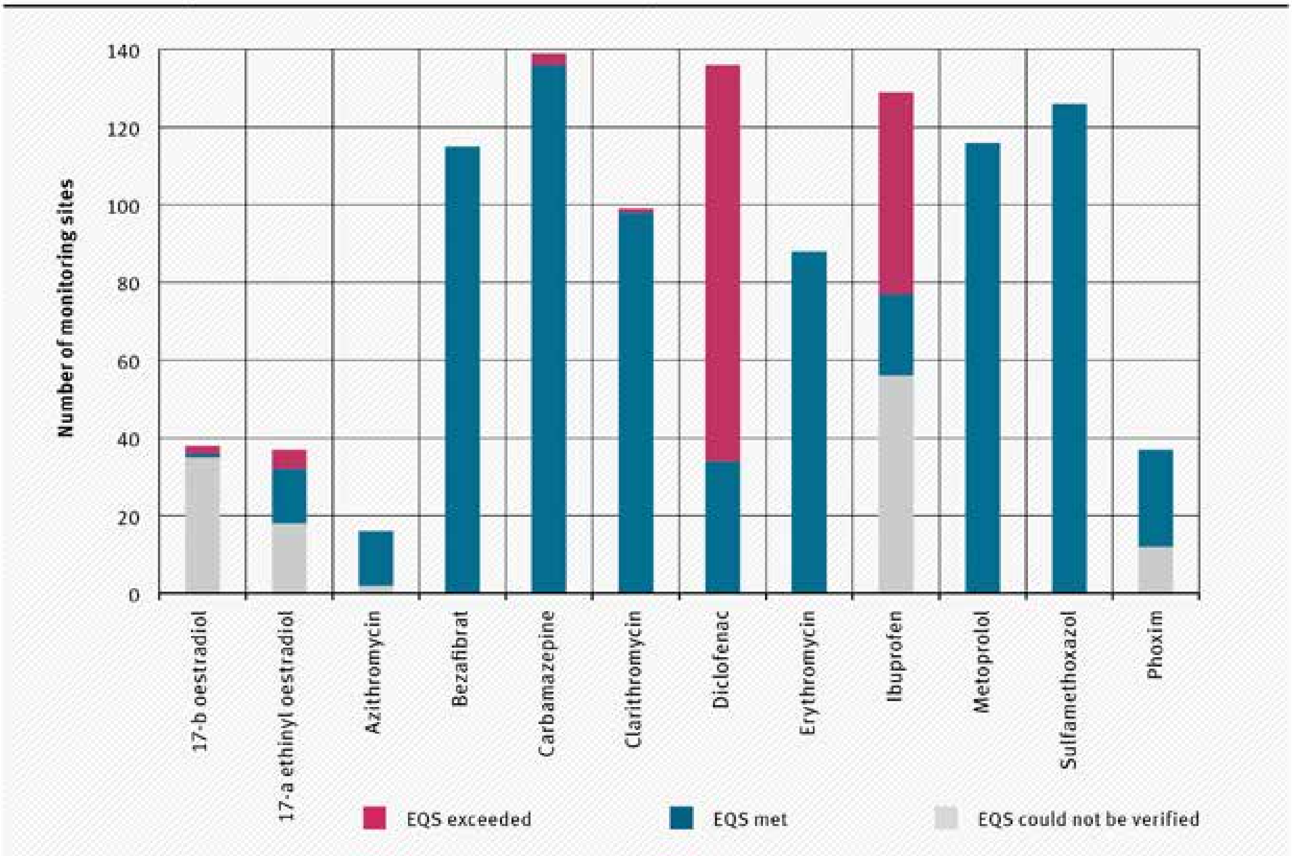
5.2.8 Pharmaceuticals

Until now, the Ordinance on Surface Waters has not defined EQS for human pharmaceuticals. However, environmental quality standard proposals have been drafted at both European and national level (see Table 17).

Small highland river close to the source
Source: Stephan Naumann

Figure 27

Comparison of annual means in 2013–2015 with the proposed environmental quality standards for pharmaceuticals (LAWA monitoring sites)



Source: German Environment Agency based on data supplied by LAWA

Table 17

Proposed environmental quality standards for pharmaceutical active ingredients

Name of substance	Proposed environmental quality standard in µg/l
17-α ethinyl oestradiol	0.000035
17-β oestradiol	0.00004
Azithromycin	0.09
Bezafibrate	2.3
Carbamazepine	0.5
Clarithromycin	0.13
Diclofenac	0.05
Erythromycin	0.2
Ibuprofen	0.01
Metropolol	43
Sulfamethoxazol	0.6

Source: EU Dossier 2017, Wenzel et al. 2015

Comparing the proposed environmental quality standards with the annual means for 2013–2015 at LAWA monitoring sites (Figure 27) reveals isolated incidences where these levels were exceeded in the case of the human pharmaceuticals carbamazepine, clarithromycin and the hormonally active agents 17-α ethinyl oestradiol and 17-β oestradiol. Exceedance is more frequent in the case of diclofenac and ibuprofen. In the case of ibuprofen, the hormones and the veterinary pharmaceutical phoxim, compliance with the AA-EQS or the environmental quality standard proposals cannot always be assessed, because the limit of quantification exceeds the target value.

5.2.9 Chemical status

For the substances listed in Annex 8 of the Ordinance on Surface Waters (see chapter 5.2.3), § 4 of the Ordinance requires the preparation of an inventory of emissions, discharges and losses. In the first inventory report on priority substances, the Laender were unable to ascertain inputs of all these substances into water bodies (LAWA 2016a). This highlights the fact that diffuse sources are also responsible for emissions of the substances regulated by the Environmental Quality Standard Directive (cf. also chapters 5.2.3 and 5.2.4). Table 18 contains an overview of direct discharges into water bodies reported to the PRTR (Pollutant Release and Transfer Register) for the reporting year 2014 (known as releases into water). Industrial facilities are subject to PRTR reporting obligations if they perform one of industrial activities listed in Annex I to Regulation 166/2006/EC (European PRTR Regulation) and provided they release or emit into wastewater at least one of the pollutants listed in Annex II to the European PRTR Regulation in quantities above the threshold values cited therein. If the aforementioned requirements are met, the operator is required to report emissions into the air, water, soil and the transfer of pollutants contained in wastewater to the PRTR. The PRTR is an annual reporting requirement. PRTR data is published on the website www.thru.de.

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann

Table 18

Reported emissions into water for substances listed in Annex 8 to the Ordinance on Surface Waters, reporting year 2014

Substance	Emissions into water	Unit
1,2-dichloroethane	38.5	kg/a
Benzene	252	kg/a
Lead and compounds	5,570	kg Pb/a
Cadmium and compounds	477	kg Cd/a
Di-(2-ethylhexyl)phthalate (DEHP)	1,170	kg/a
Dichloromethane	182	kg/a
Dioxins and furans	0.000172	kg TEQ/a
Diuron	27.74	kg/a
Endosulfan	0.00	kg/a
Fluoranthene	4.00	kg/a
Hexachlorobenzene (HCB)	0.00	kg/a
Hexachlorocyclohexane	2.77	kg/a
Isoproturon	5.65	kg/a
Nickel and compounds	25,200	kg Ni/a
Nonylphenol and nonylphenol ethoxylates (NP/NPEs)	942	kg/a
Ocytlphenols and octylphenol ethoxylates	111	kg/a
PAH	57.5	kg/a
Mercury and compounds	204	kg Hg/a
Trichloromethane	683	kg/a

Source: German Environment Agency after PRTR 2016

It is noticeable that the reported total quantities released in the reporting year 2014 (Table 18) for the substances diuron (pesticide, 27.74 kg/a), nonylphenol and nonylphenol ethoxylates (NP/NPEs) (942 kg/a) and octylphenol and octylphenol ethoxylates (111 kg/a) (both organic substances) are several times higher than the reported total quantities released in the reporting year 2011. For these three substances, in the reporting year 2014, urban waste-water treatment plants with a capacity of 100,000 population equivalents made up the bulk of reporting PRTR operations. Since 2011, we have seen a steady increase in urban waste-water treatment plants reporting releases into water of diuron, nonylphenol and octylphenol under the PRTR, with some of them indicating high substance loads in 2014:

- Emschergenossenschaft Emscherkläranlage: 17.7 kg/a diuron (share of 64 %)
- Emschergenossenschaft Emscherkläranlage: 510 kg/a nonylphenol and nonylphenol ethoxylates (NP/NPEs) (share of 55 %)
- Kläranlage Niederrad: 63 kg/a octylphenols and octylphenol ethoxylates (share of 57 %) (PRTR 2016).

Rather than an effective increase in emissions, this is thought to be attributable to the fact that greater attention is being devoted to emissions of priority substances from public wastewater discharges, leading to more frequent and more intensive measurements of the discharge load.

There are currently no approved applications for the use of diuron as a pesticide in Germany. Under the Biocide Ordinance (EU 528/2012), the active substance diuron is notified as a protective coating and a preservative for construction materials. This active substance is currently being assessed under the EU's existing active substances programme. Until a decision is reached on the licensing of this active substance, biocide products containing it may be marketed and used without a licence for the product types specified. Diuron enters wastewater treatment plants, for example, when used in house paint via rainwater.

Nonylphenol and octylphenol and their ethoxylates are a particular cause for concern within the context of the EU Chemicals Ordinance REACH, due to their hormonal effect. In the EU, they are subject to certain usage restrictions. For nonylphenol and its ethoxylates, the EU is currently discussing extending the restriction to use in textiles. Licensing is mandatory for the manufacture and use of nonylphenol and octylphenol ethoxylates. However, they may be imported, for example with textiles, and in dyes, paints and glues, and enter the wastewater treatment plant e.g. when washed (UBA 2016).

For the assessment of chemical status, the Water Framework Directive also adopts the "one out all out" approach. In other words, if the environmental quality standard is exceeded for one substance, the chemical status is "not good". In Germany, the chemical status of 100 % of bodies of surface water is assessed as "not good" (LAWA 12016b) because the biota environmental quality standard for mercury is consistently exceeded. Measurements for mercury in fish are not available for all rivers. Since the concentration of mercury in fish exceeds the environmental quality standard even in largely unpolluted waters, it is assumed to be true of all surface waters, and the available results have therefore been transferred (see also the Brochure "The Water Framework Directive – The status of German waters 2015"). Despite this, assessment of the other substances that determine chemical status based on the environmental quality standards is needed.

Small highland river close to the source
Source: Stephan Naumann

Whereas Germany has been measuring suspended solids/sediment for many years, a coordinated method of investigation for measuring biota was not adopted by LAWA until 2016. For this reason, only a few measurements are available that were collected using this method of investigation. Table 19 lists measurement results for Mecklenburg Western Pomerania, Lower Saxony and Saxony.

Table 19

Results of pollutant measurements in biota in rivers, 2013–2015

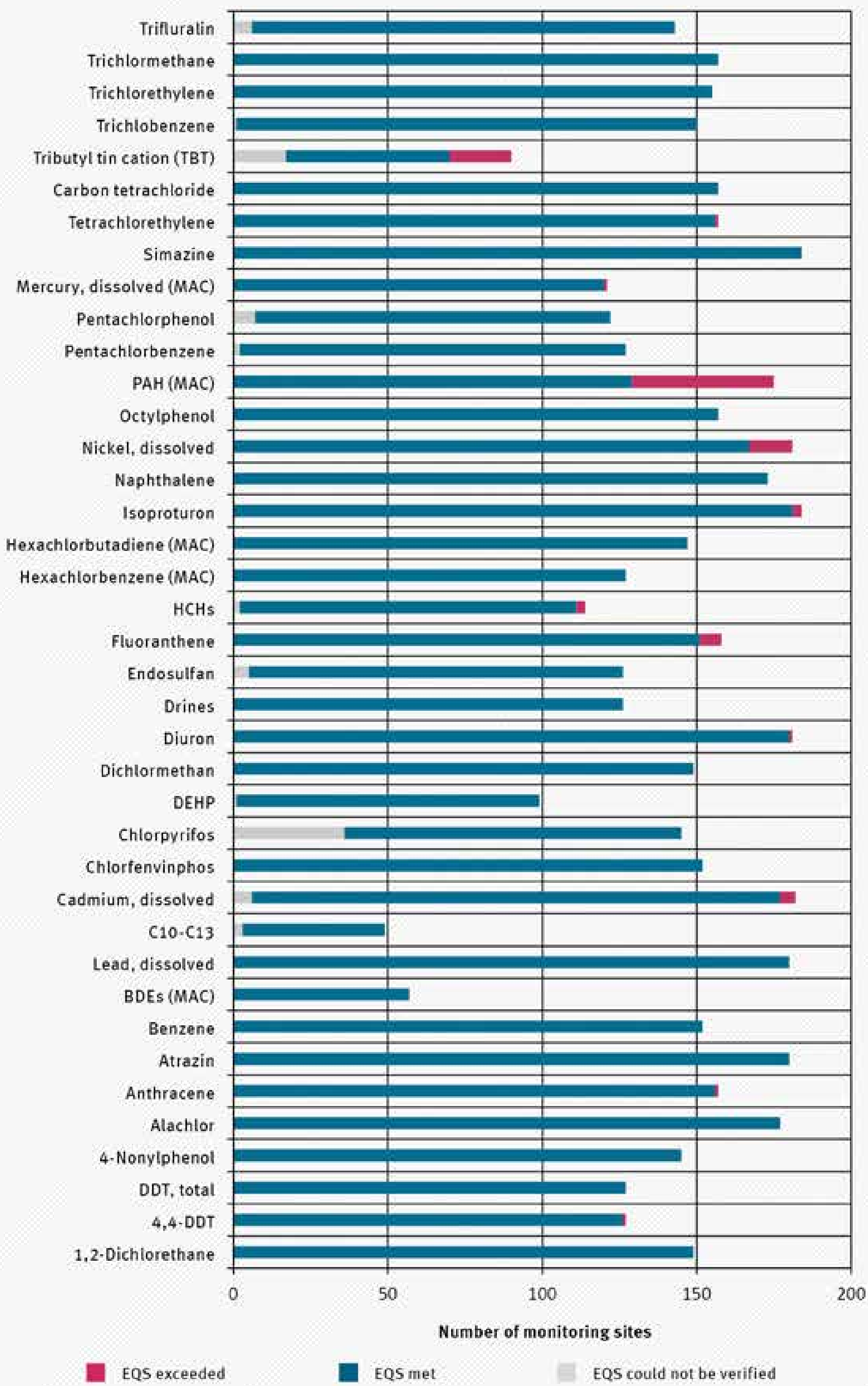
Name of substance	Land	Concentration range (min – max) in µg/kg (wet weight)*	Biota EQS in µg/kg (wet weight)
Mercury	Mecklenburg Western Pomerania	33–264	20
Dicofol	Mecklenburg Western Pomerania	<0.02	33
BDE	Mecklenburg Western Pomerania	0.081–0.599	0.0085
HBCDD	Mecklenburg Western Pomerania	<0.2	167
HCB	Mecklenburg Western Pomerania	<0.02–0.140	10
Hexachlorobutadiene	Mecklenburg Western Pomerania	<0.02	55
PFOS	Mecklenburg Western Pomerania	<2.0–5.0	9.1
Mercury	Lower Saxony	22–200	20
Fluoranthene	Lower Saxony	2.5–23	30
Benzo[a]pyrene	Lower Saxony	<0.1–0.3	5
Dicofol	Lower Saxony	<10	33
BDE	Lower Saxony	0.071–0.351	0.0085
Dioxins	Lower Saxony	0.000057–0.001017 **	0.0065 **
Total: Heptachlor, heptachloroepoxide	Lower Saxony	<0.02–0.256	0.0067
HBCDD	Lower Saxony	<150	167
HCB	Lower Saxony	<10	10
Hexachlorobutadiene	Lower Saxony	<10	55
PFOS	Lower Saxony	<5.0–11.0	9.1
Mercury	Saxony 2015	55.8–175	20
Dicofol	Saxony 2015	<1–4.82	33
BDE	Saxony 2015	0.043–1.77	0.0085
Dioxins	Saxony 2015	0.00023–0.00377 **	0.0065 **
Total: Heptachlor, heptachloroepoxide	Saxony 2015	<0.01–0.0288	0.0067
HBCDD	Saxony 2015	<10	167
HCB	Saxony 2015	0.291–11.6	10
Hexachlorobutadiene	Saxony 2015	<0.05–0.474	55
PFOS	Saxony 2015	1.62–10.8	9.1

* Fish species analysed: Mecklenburg Western Pomerania: Perch, roach; Lower Saxony: Bream, chub, roach; Saxony: Chub, common bream, pike; Mussels analysed: Dreissena, Corbicula
** in µg/kg TEQ

Source: LUNG 2016, NLWKN 2016, LfLUG 2016

Figure 28

Assessment of the environmental quality standard of priority substances for chemical status (only water samples, LAWA monitoring sites, 2013–2015)



Source: German Environment Agency based on data supplied by LAWA

Over the period 2013–2015, the AA-EQS and MAC-EQS for dissolved and total concentrations were met at the LAWA monitoring sites by 27 of the 38 substances that were already regulated in 2011 (Figure 28). Exceedances occurred in the substances/ substance groups PAH (MAC-EQS), tributyltin cation, nickel (dissolved, data in Figure 28 does not refer to bioavailable concentrations), fluoranthene (MAC-EQS), cadmium (dissolved), HCH, isoproturon, diuron, 4,4-DDT and anthracene (in descending order of the number of monitoring sites with exceedance).

For the 12 newly regulated substances, the environmental quality standards were met for aclonifen and quinoxyfen, and exceeded in individual cases by bifenox, cybutryne, cypermethrin, dichlorvos and terbutryn (see chapter 5.2.5). For mercury, dicofol, dioxins, PFOS, HBCDD and heptachlor, the results from biota monitoring should be used as a primary indicator. As shown in Table 18, all measured concentrations exceed the biota EQS for mercury and BDE, and exceedance of HCB and PFOS is also ascertained in selected cases. In the case of heptachlor, even measurements in biota proved problematic in achieving a limit of quantification below the biota-EQS. Exceedances for total heptachlor in both Lower Saxony and Saxony are due to high concentrations of a metabolite (heptachlor epoxide (cis or trans)).

Analysis of the data indicates that improved analysis methods are needed for some substances in order to review the EQS, both for total water samples and for analyses in biota (see chapter 2.2).

Transverse structure in the Mulde (Raguhn)
Source: Stephan Naumann


6

6 Lakes and reservoirs

6.1 Basis for assessment

6.1.1 Lake types

Unlike streams and rivers, no comprehensive biocoenotic characterisation of lakes exists as yet. The typology used for standing waters in Germany follows an approach based initially on abiotic factors. The following criteria were used to demarcate the individual lake types:

- Ecoregion
- Geology
- Size of lake
- Influence of the catchment area and
- Stratification properties (cf. Table 20),

UBA studies were also involved in identifying the specific reference biocoenoses (chapter 6.1.2).

6.1.2 Biological quality elements

The ecological status of lakes is assessed using the biological quality elements of invertebrate fauna, fish fauna and aquatic flora (chapter 4.2). Macrophytes and phytobenthos have been combined into one assessment element. Phytoplankton represents the second floristic element. The identified species occurring and the individuals of each species are counted in order to describe the status. In the case of fish fauna, the age structure of the population is additionally determined, and in the case of phytoplankton, the biomass of the algae. The worst-rated quality element determines the overall assessment of a water body's ecological status. As of 2016, the assessment methods used for biological quality elements under the EU Water Framework Directive (WFD) are set out in the Ordinance on Surface Waters (Annex 6 to the OGewV). Detailed descriptions of all biological assessment methods are available for downloading at http://www.gewaesser-bewertung.de.

Table 20

Lake types in Germany

Ecoregions 4 and 9: The Alps and Pre-Alpine region
Type 1: Polymictic pre-Alpine lake
Type 2: Stratified[1] pre-Alpine lake with a relatively large catchment area[2]
Type 3: Stratified pre-Alpine lake with a relatively small catchment area
Type 4: Stratified Alpine lake
Ecoregions 8 and 9: Central German Highlands
Type 5: Stratified calcareous[3] Central German Highland lake with a relatively large catchment area
Type 6: Polymictic, calcareous Central German Highland lake
Type 7: Stratified calcareous Central German Highland lake with a relatively small catchment area
Type 8: Stratified siliceous Central German Highland lake with a relatively large catchment area
Type 9: Stratified siliceous Central German Highland lake with a relatively small catchment area
Ecoregions 13 and 14: Northern German lowlands
Type 10: Stratified lowland lake with a relatively large catchment area
Type 11: Polymictic lowland lake with a relatively large catchment area
Type 12: River-lake in lowlands
Type 13: Stratified lowland lake with a relatively small catchment area
Type 14: Polymictic lowland lake with a relatively small catchment area
Special types (all ecoregions)
Type 88: Special type of natural lake (e.g. peat lake, beach lake, oxbow lake or backwater)
Type 99: Special type of artificial lake (e.g. dredged lake)

1 A lake is classified as stratified if the thermal stratification at the deepest point of the lake remains stable for at least 3 months
2 Relatively large catchment area: Ratio of the area of the overground catchment area (with lake area) to the volume of the lake (volume ratio VQ) > 1.5 m^2/m^3; relatively small catchment area: VQ ≤ 1.5 m^2/m^3
3 Calcareous lakes: Ca^{2+} ≥ 15 mg/l; siliceous lakes: Ca^{2+} < 15 mg/l

Source: German Environment Agency after Annex 1 of the Ordinance on Surface Waters (OGewV)

6.1.3 Hydromorphological quality elements

The hydromorphological quality elements for lakes are hydrological regime and morphology. The hydrological regime, which includes water level dynamics, water residence time and link to groundwater, and morphology, which includes depth variation, structure and substrate of the lake bed and structure of the shore zone, are only used in a supporting capacity to assess a lake water body. The decisive element for assessing a lake water body under the Water Framework Directive are biological quality elements.

For the quality element "morphology", a uniform national method has now been developed for recording and assessing the shore structures of natural lakes. It distinguishes 8 lake shore types according to their incline and bedrock, which characteristics are described in profiles (LAWA 2015a).

1. Shallow to medium-steep sandy shores
2. Shallow to medium-steep shores with cohesive soils
3. Peat shores
4. Shallow to medium-steep shingle shores
5. Steep shores with cohesive soils
6. Steep gravel/shingle shores
7. Steep rubble/scree shores
8. Rocky shores

In order to correlate biological colonisation and lake shore type more closely, the shallow water zones were further differentiated according to the criteria of shade, width of shallow water zone, wind exposure, and influence of water level fluctuations (LAWA 2015b). The hydromorphological references are compared with the current structural features of the lake shore. The degree by which the current structural features deviate from the reference is known as the structural quality of the lake shore, and graded into 5 classes. Class 1 refers to an unchanged status, and class 5 to a status furthest removed from the reference (extensively to completely transformed). In an overview process using maps and aerial images, homogeneous sections of lake shores which are at least 100 m and no more than 1,000 m long are assessed. The spatial sections of the shallow water zone, the shore zone and the riparian zone are assessed separately from one another according to specific criteria based on the "worst case principle". The individual results for the spatial sections are combined into a structural quality score for a section of lake shore by means of averaging.

For an audit of pressures pursuant to Article 5 of the Water Framework Directive, furthermore, selected hydromorphological pressures in lakes are recorded in order to assess whether a lake is at risk of failing to meet the WFD objectives. The pressures are identified according to the following features:

- Anthropogenic influences on the water level
- Changes to the shore structure (obstruction, build-up, bank inclination)
- Changes in the structural conditions (use, construction work) in the immediate vicinity of the lake
- The absence of riparian buffer strips to act as a buffer zone between the surrounding land and the lake.

Changes to the shore structure are relevant to the ecological status of a lake if they affect significant portions of the shore length. A good ecological status is considered to be at risk if 70 % of the shore length fails to exhibit the typical characteristics of that water body. For lakes in Germany, it has been found that nutrient inputs into the water body pose a greater threat to target achievement than hydromorphological pressures.

Table 21

Spatial assessment levels for lake shore structure, assessment criteria and sample parameters

Lake shore zone	Criterion	Sample parameters and assessment yardstick
Shallow water zone	A1 Changes in the reed stock	Homogeneity of the reed stock (homogeneous / isolated / lacking)
	A2 Damage structures	Mooring, pontoons, jetties, harbour installations, navigation channels
Shore zone	B1 Bank obstruction	Pile-driven or brick-built structures, poured structures, wooden obstructions
	B2 Damage structures	Jetties, grassland, individual structures, arable land, transport land, harbour installation
Riparian zone	C1 Land use	Forests, grassland, arable land, sports and leisure facilities, industrial/commercial land

Source: LAWA 2015a

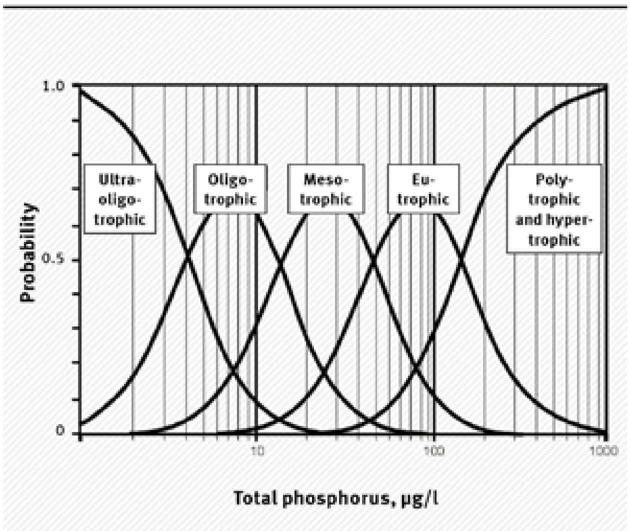
6.1.4 General physico-chemical quality elements

Values have been defined for a very good (background levels) and good ecological status of lakes (benchmarks) (Annex 7 to the Ordinance on Surface Waters). The parameters for lakes are total phosphorus concentration ranges and limit of visibility (transparency) for the various different trophic levels and lake types. When determining the reference trophic level, for many lake types, it is expedient to distinguish between sub-types based on the phytoplankton assessment. Compliance with the benchmark, particularly with regard to total phosphorus and limit of visibility, may positively impact the biological quality elements fish, macrophytes and phytobenthos, diatoms and macroinvertebrates, but will not necessarily lead to a "good" status for these bio-elements, since the corresponding assessment techniques may be calibrated to other ecologically effective stressors.

The definitions in Annex 7 to the Surface Water Ordinance are based on the assessment methods developed by LAWA in 1999. In recent decades, lakes in Germany have been assessed primarily according to their trophic situation, which describes pollution with nutrients and the response of plankton algae to this nutrient supply. Increased nutrient loads and concentrations lead to an increase in plant biomass production, particularly phytoplankton. In this respect, phosphorus plays a key role as a limiting factor for the primary production of phytoplankton. An initial quantification of the effects of increased nutrient inputs was carried out by Vollenweider in 1975, and was tested on various water types within the context of a 1982 OECD study (cf. Figure 29).

Figure 29

Probability distribution of the trophic classes of a lake depending on total phosphorus levels (annual means), after Vollenweider



Source: Vollenweider 1979

This classification system forms the basis for the assessment system of lakes in Germany, which was published in 1999 by LAWA. On the basis of these LAWA guidelines, trophic classification is based primarily on the parameters total phosphorus (TP) concentration, chlorophyll a and limit of visibility (Table 22).

Table 22

Total phosphorus and chlorophyll a concentration, limit of visibility (transparency) and trophic levels according to LAWA (1999) – using stratified lakes as an example

Total phosphorus concentration in spring in µg/l	Total phosphorus concentration in summer in µg/l	Chlorophyll a in µg/l in epilimnion	Limit of visibility [m]	Trophic level
≤ 11	≤ 8	≤ 3.0	≥ 5.88	Oligotrophic
> 11–58	> 8–45	> 3.0–9.7	< 5.88–2.40	Mesotrophic
> 58–132	> 45–107	> 9.7–17	< 2.40–1.53	Weakly eutrophic
> 132–295	> 107–250	> 17–31	< 1.53–0.98	Highly eutrophic
> 295	> 250	> 31–56	< 0.98–0.63	Weakly polytrophic
> 500	> 500	> 56–100	< 0.63–0.40	Highly polytrophic
		> 100	< 0.40	Hypertrophic

Source: LAWA 1999

Conversion of the existing nutrients into plant biomass depends not only on the nutrient concentrations, but also on the shape and position of the lake basin and on the hydrology. Thus deep lakes with stable summer temperature stratification, a small catchment area and little water exchange are naturally not very productive (the reference condition is oligotrophic (= low in nutrients)), whereas shallow, constantly mixed lakes tend to convert nutrients more effectively (greater algae production) (the reference condition is eutrophic (= rich in nutrients)). The LAWA assessment system makes allowance for this by allocating a quality class based on the deviation of the actual trophic status from the potential natural trophic status (i.e. the status which would occur without (further) anthropogenic influence). The 7-point scale ranging from class 1 (no nutrient pollution) to class 7 (an excessively high level of nutrient pollution) has since been converted to an 8-point scale, prompted by the latest biological analysis results (sub-division of the trophic level "mesotrophic" (Table 23):

Table 23

LAWA index 1999, trophic classes and abbreviations

LAWA index	Trophic class	Abbreviation
0.5–1.5	Oligotrophic	O
> 1.5–2.0	Mesotrophic 1 *	m1
> 2.0–2.5	Mesotrophic 2 *	m2
> 2.5–3.0	Eutrophic 1	e1
> 3.0–3.5	Eutrophic 2	e2
> 3.5–4.0	Polytrophic 1	p1
> 4.0–4.5	Polytrophic 2	p2
> 4.5	Hypertrophic	H

* Sub-dividing the trophic level "mesotrophic" deviates from the original LAWA system (1999), but can probably be differentiated and justified by biological findings.

Source: After LAWA 1999

6.1.5 Monitoring network for reporting

The LAWA network of monitoring sites has been set up in Germany for the EC Nitrates Directive and for reporting to the European Environment Agency. The LAWA network of monitoring points for standing waters currently comprises 68 representative points, including surveillance monitoring sites and sites in the operational monitoring network (cf. chapter 4.3.1). The data from these monitoring sites provides the basis for the assessments outlined in chapter 6.2.2 below.

6.2 Status assessment

6.2.1 Hydromorphology

In terms of the earth's history, lakes are surface forms that have existed for a comparatively short period. Lake morphology is directly linked to the genesis of the lake, and influences the substance balance in the water (chapter 6.1.4). The grain size of the sediment can also influence the lake shape. Fine-grained clay sediment may be very stable and encourage the formation of steep slopes, whereas coarse-grained sediment such as sand or gravel leads to shallow slopes. The immediate bank form is also shaped by the lake genesis and protruding sediment.

Uniform nationwide assessment results for the structural quality of lake shores based on the newly developed method (chapter 6.1.3) are anticipated for the third WFD management cycle. In Schleswig-Holstein, 18 lakes were assessed in accordance with the LAWA overview method. Assessments of the shallow water zone are divided between class 2 (8 lakes) and class 3 (10 lakes). The shore zone is assessed with class 1 (Selenter See), class 2 (7 lakes) and class 3 (10 lakes). Assessment of the riparian zone is less favourable: One lake achieves class 2 (Selenter See), six lakes class 3, eight lakes class 4 and three lakes class 5. In the overall assessment, only Schluensee and Selenter See achieve class 2; the other 16 lakes are assessed as class 3 (Fell and Fell 2016).

6.2.2 Nutrient and trophic status

The biggest problem for lakes in Germany remains the excessive inputs of nutrients and the resulting over-fertilisation (eutrophication) of the lakes. High concentrations of the nutrients phosphorus and nitrogen may accelerate algal growth in stagnant waters. Possible adverse consequences include high turbidity, oxygen deficits, fish mortality, restrictions on use for drinking water, and allergic reactions in bathers. The limiting nutrient for algal development is usually phosphorus. During high summer, however, nitrogen limitation may also occur in lakes. Under such conditions, there is the possibility of the mass development of blue-green algae, which are capable of absorbing nitrogen from the air. The influence of wastewater as a source of pollution has decreased significantly in recent years, thanks to improved wastewater treatment technology and the introduction of phosphate-free detergents. The diagrams below illustrate the annual concentrations of chlorophyll, nitrate nitrogen and phosphorus in selected lakes.

Phosphorus concentrations in the **Alpine and pre-Alpine lakes** and in **Brombachsee** have been reduced as a result of improved wastewater treatment technology and the construction of perimeter sewage systems.

In **Lake Constance**, total phosphorus concentrations increased almost fivefold between 1960 and 1980, while the biomass of plankton algae quadrupled over the same period. Today, phosphorus concentrations are below the specified limit range for total phosphorus (refer also to the website https://www.umweltbundesamt.de/themen/wasser/seen/zustand).

Starnberger See, which was low in nutrients until around 1950, recorded rising levels of nutrient pollution from the mid- to late 1960s as a result of wastewater discharges. Since the 1970s, measures have been carried out in the wastewater and agriculture sectors. However, a significant reduction in phosphorus levels inside the lake was not seen until around the mid-1980s, due to the long retention period; by the late 1990s, total phosphorus concentrations had been reduced to below 10 µg/l (Figure 30).

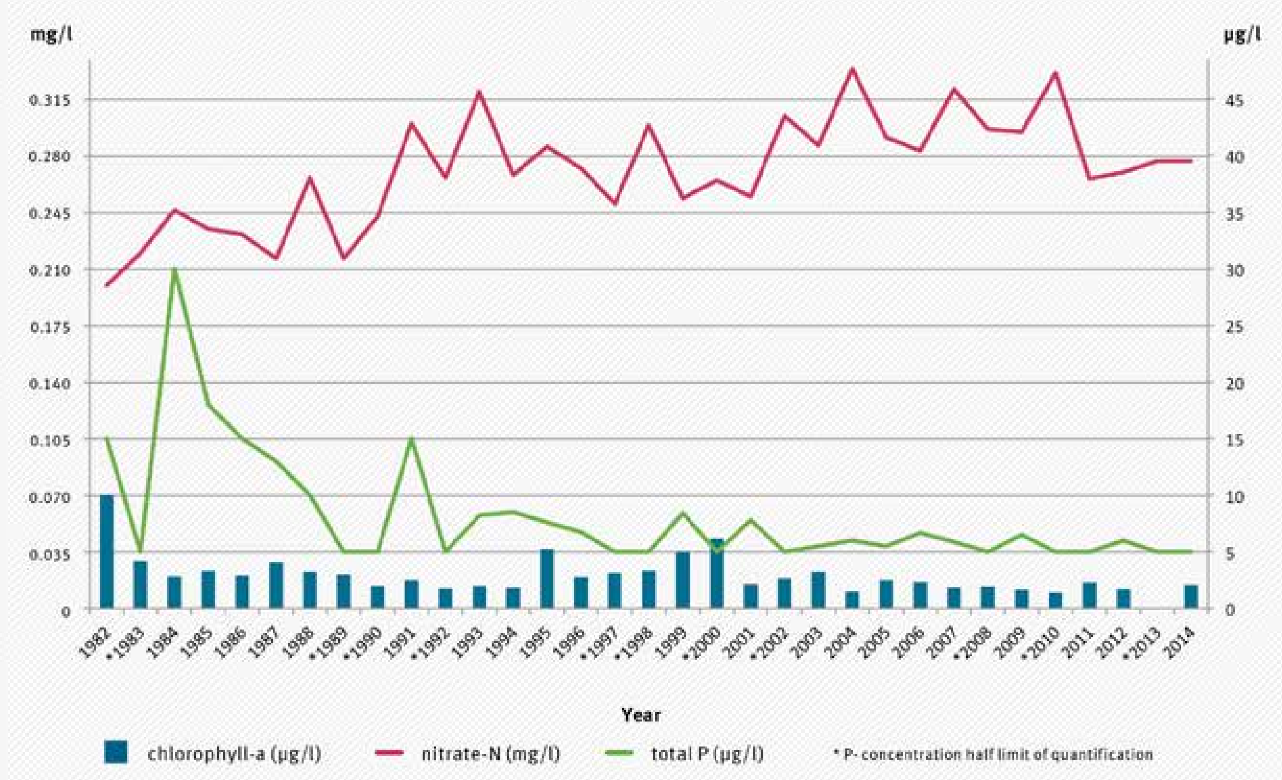
Chiemsee (Figure 31) indicates a similar development to Starnberger See. Although this is Germany's third-largest lake, unlike Starnberger See it has only a relatively short retention period of one year. Thanks to good water mixing and a shallow depth, the nutrient situation improved quickly. At present, the lake is in the process of transition to a mesotrophic status. As in Starnberger See, phosphorus is the limiting factor.

Some of the lakes of the **Central German Highlands** have likewise shown improvements in recent years, as illustrated by the examples of Brombachsee (Figure 32) and Edersee Reservoir (Figure 33). Brombachsee, a reservoir lake in the Franconian lake district, is phosphorus-limited. Over the past ten years, the status of the lake has shown a marked improvement. Annual average nitrate levels are now in the region of 0.15 mg N/l. The lake is an important local recreation facility for the Nuremberg conurbation area, and also serves as a flood defence for the Altmühl valley.

Morphologically effective interventions into the bank area, such as bathing and mooring areas, can influence the water biology

Figure 30

Starnberger See (annual means 1982–2014, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Bayerisches Landesamt für Umwelt

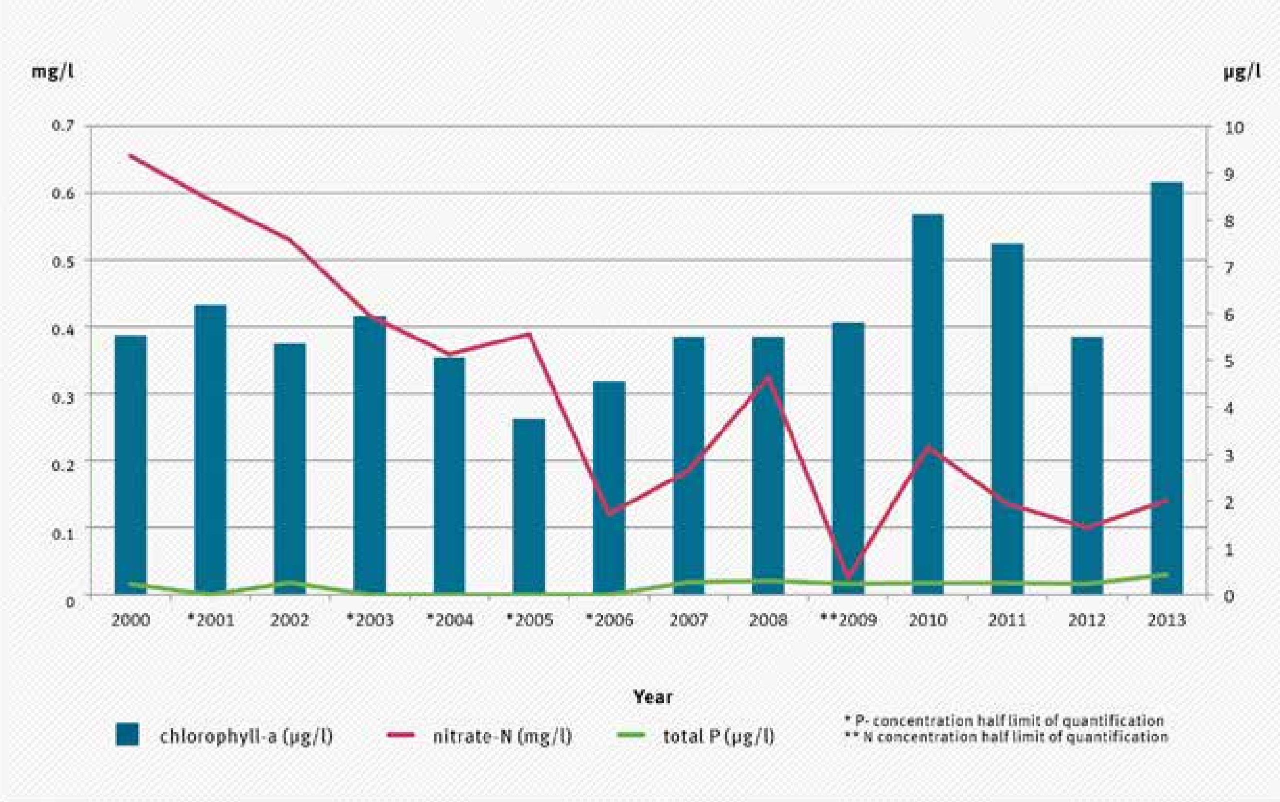
Figure 31

Chiemsee (annual means 1982–2014, chlorophyll-a, nitrate-N and phosphorus)

Source: German Environment Agency based on data supplied by the Bayerisches Landesamt für Umwelt

Figure 32

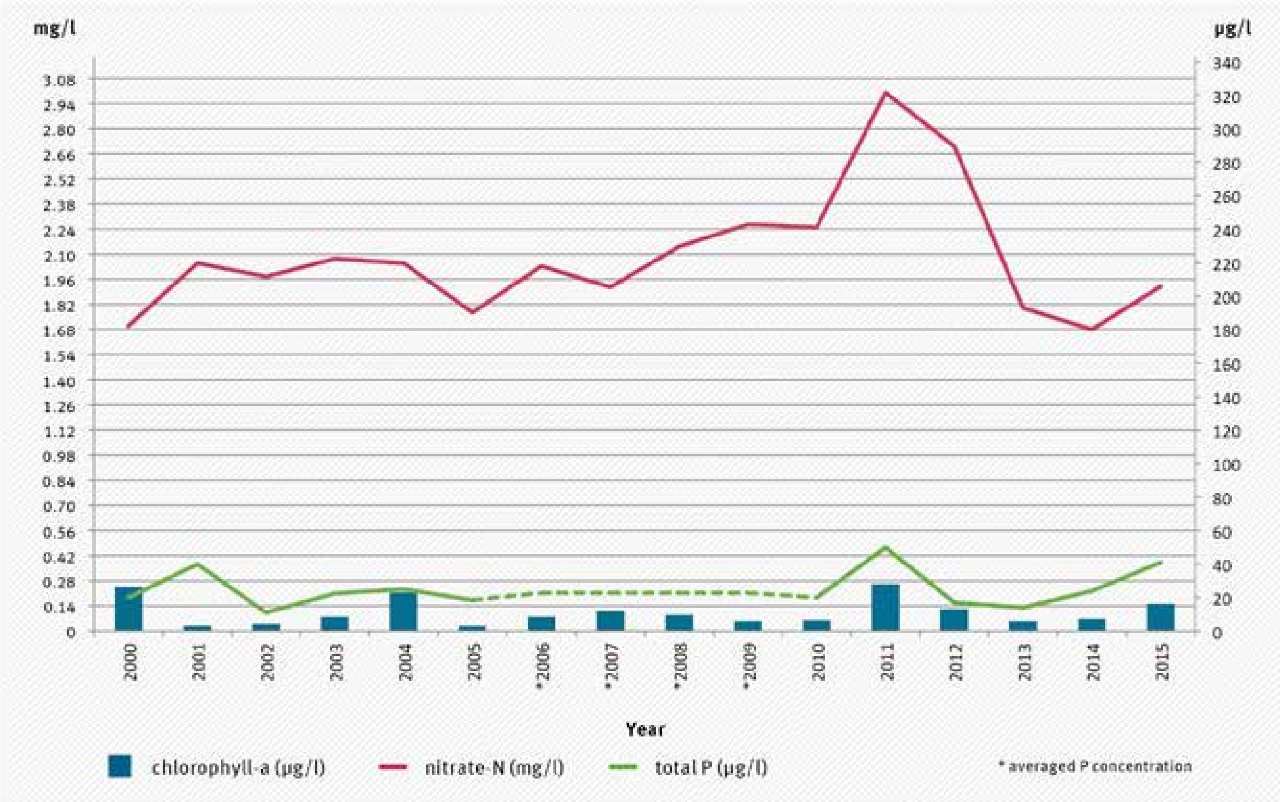
Brombachsee (annual means 2000–2013, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Bayerisches Landesamt für Umwelt

Figure 33

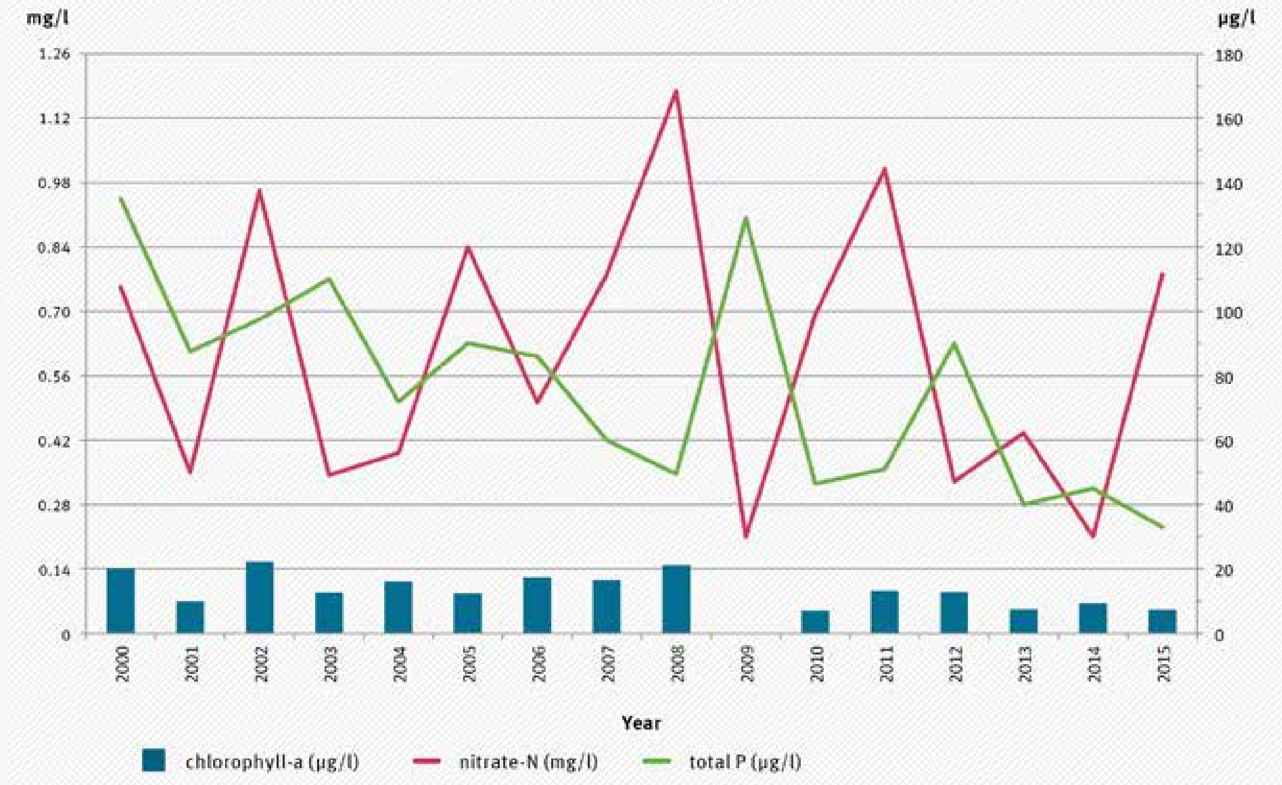
Edersee Reservoir (annual means 2000–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Hessian State Agency for Environment and Geology

Figure 34

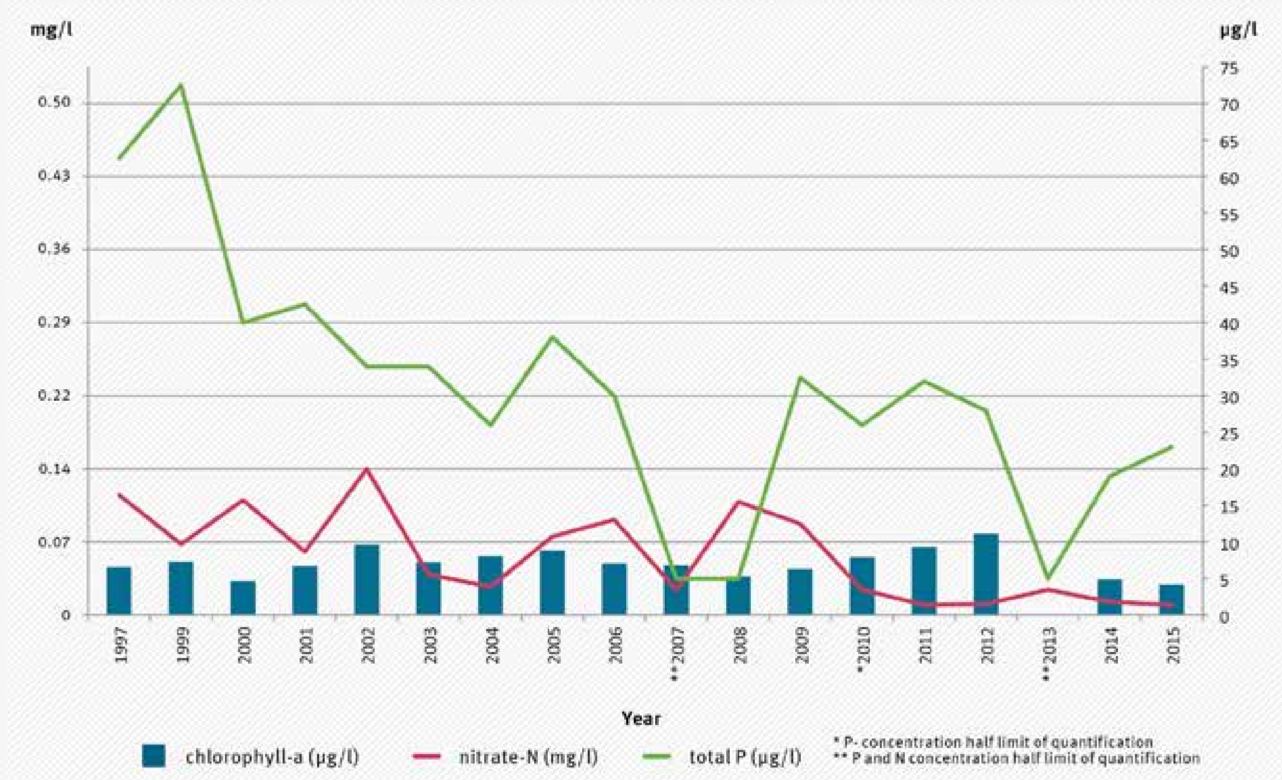
Kummerower See (annual means 2000–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Mecklenburg-Western Pomerania State Agency for Environment, Nature Conservation and Geology

Figure 35

Plauer See (annual means 2000–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Mecklenburg-Western Pomerania State Agency for Environment, Nature Conservation and Geology

The Edersee Reservoir, a reservoir lake in Hesse, supplies water to the Mittelland Canal and the Oberweser, and is also used as a local recreation facility and to generate hydropower. Nitrate concentration levels remain unchanged at a high average level of 2.2 mg N/l.

In the past, the lakes of the **North German lowlands**, particularly in Mecklenburg-Western Pomerania and Berlin, were heavily polluted with nutrients resulting from inadequate wastewater technology and diffuse emissions from agriculture. However, the influence of wastewater as the cause of eutrophication has diminished considerably in recent years. Figures 34 and 35 illustrate conditions in Kummerower See and Plauer See.

Both of these are shallow lakes with an average depth of 6 metres (Plauer See) and 8 metres (Kummerower See) respectively, and a short retention period. Agricultural use predominates over a large catchment area (around 1,200 km² in each case). The trout farming practised in Plauer See since the 1970s has contributed to the lake's eutrophication. Today, Plauer See is nitrogen-limited.

The **Upper Havel** (Figure 36) is a lake-like extension of the river Havel in Berlin, which absorbs discharge from Tegeler See. As a result of the heavy eutrophication of Tegeler See due to sewage irrigation practices in the 1970s and 1980s, phosphorus concentrations in the Upper Havel remained high throughout the 1990s. The phosphate precipitation plant constructed in the 1980s in the inflow to Tegeler See (Tegeler Fließ) substantially improved conditions in Tegeler See and the Havel. The depth aeration system constructed in Tegeler See in 1995 actually caused total phosphorus levels to deteriorate, since circulation in the deep water of the lake during the summer distributed phosphates throughout the lake. Nitrogen levels have improved in the past 15 years and now average at 1 mg N/l. The lake is phosphorus-limited.

Zeuthener See (Figure 37), on the border between the states of Berlin and Brandenburg, is a nitrogen-limited shallow lake. This is a nutrient-rich, polytrophic lake with a high level of phytoplankton production. The low nitrate levels of 0.2 mg N/l are attributable to the limiting of nitrogen. The reference status of the lake is eutrophic.

In **Schweriner See** (Figure 38), phosphorus pollution levels have also been reduced since 1994 by diverting the city of Schwerin's wastewater out of the lake's catch-

Figure 36

Upper Havel (annual means 1991–2015, chlorophyll-a, nitrate-N and phosphorus)

Source: German Environment Agency based on data supplied by the Senate Department for the Environment, Transport and Climate Protection Berlin ment area, and by improving wastewater treatment in a number of local communities. As well as acute oxygen problems with the formation of hydrogen sulphide in deep water, eutrophication in the lake, with phosphorus concentrations in the milligram range during peak periods, was also manifested in the regular appearance of blue-green algal bloom, the extinction of certain oxygen-loving fish, some cases of acute fish mortality, and the appearance of filamentous green algae in the riparian zone. Overall, the status of Schweriner See remains very unstable to this day.

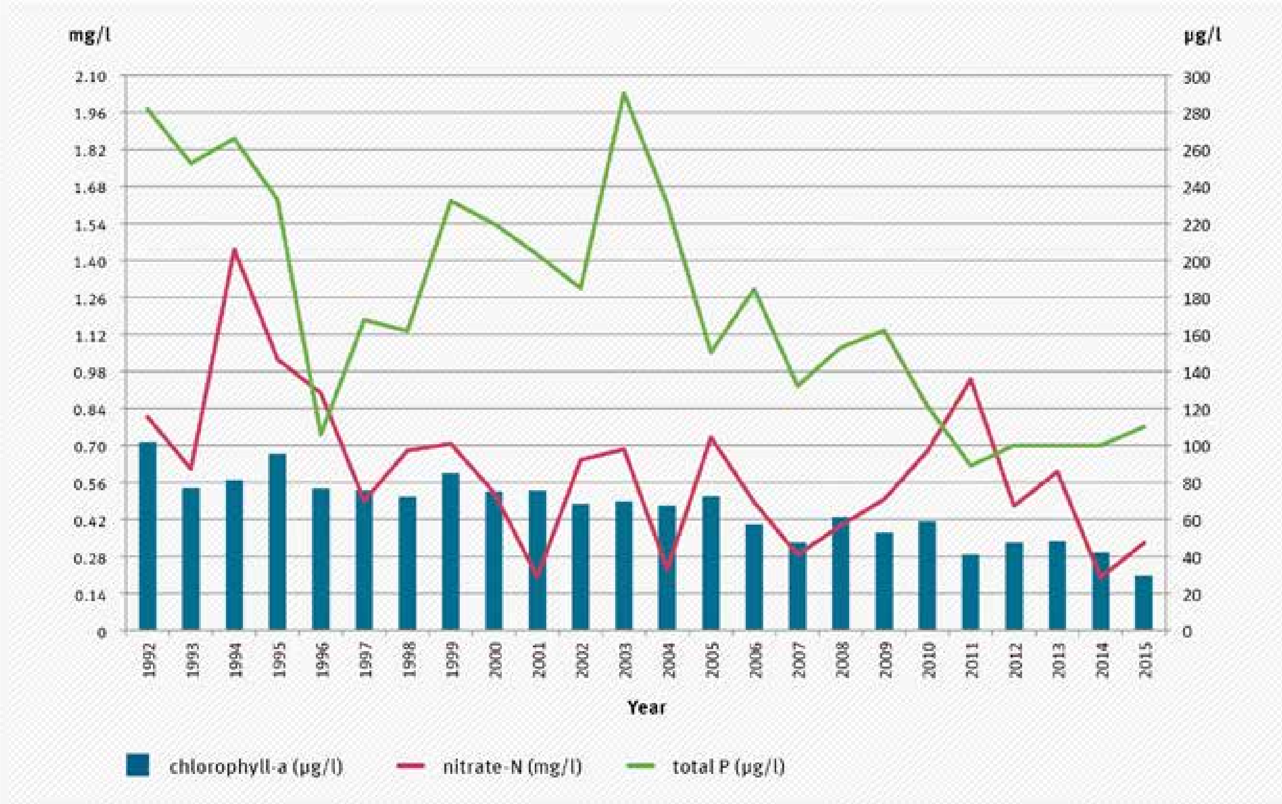
Germany's second-largest lake, the **Müritz** in the Mecklenburg Lakes region, is likewise nitrogen-limited. The high phosphorus concentrations associated with the discharge of wastewater and intensive agricultural activity in the past have improved since the 1980s, and continue to do so (Figure 39). Today, the Müritz is classed as mesotrophic to weakly eutrophic, although the bays still indicate elevated nutrient concentrations. It can be assumed that large quantities of phosphorus are still fixed in the lake sediment, and could be re-released as the oxygen concentrations decrease.

Despite persistently high nutrient pollution levels in many areas of the lowland lakes, improved wastewater treatment has led to a significant reduction in phosphorus concentrations in recent years. In future, measures to reduce eutrophication must focus in particular on diffuse nutrient emissions from agriculture. For some types of lakes, however, additional restoration measures will be needed to reduce the trophic level. However, such internal measures (deep water aeration, sediment treatment, calcite precipitation etc.) rely on a dramatic reduction in nutrient emissions from the catchment area in order to be effective.

The following Table 24 lists the trophic assessment for selected lakes since 1990. The graduation of actual status to reference status is colour-coded as per the key. Assessment indicates that in almost all lakes, the actual status is at least one trophic class higher than the reference status, and the trophic status based on one year's data only partially reflects the biological water status. For example, in the Müritz and in Plauer See, the strong fluctuations in most parameters (Figures 35 and 39) and the very different phytoplankton and zooplankton successions from year to year indicate that the status of these lake ecosystems changes from one year to the next.

Figure 37

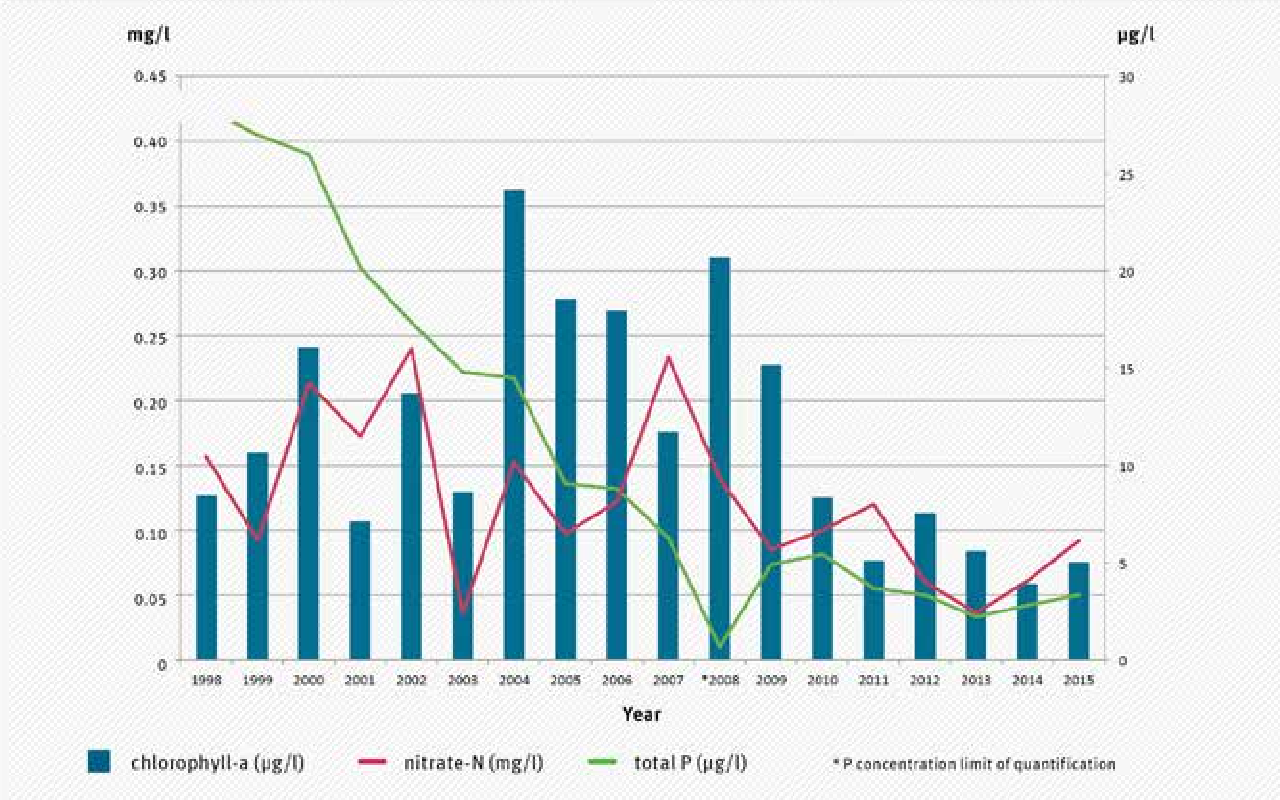
Zeuthener See (annual means 1992–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Senate Department for the Environment, Transport and Climate Protection Berlin

Figure 38

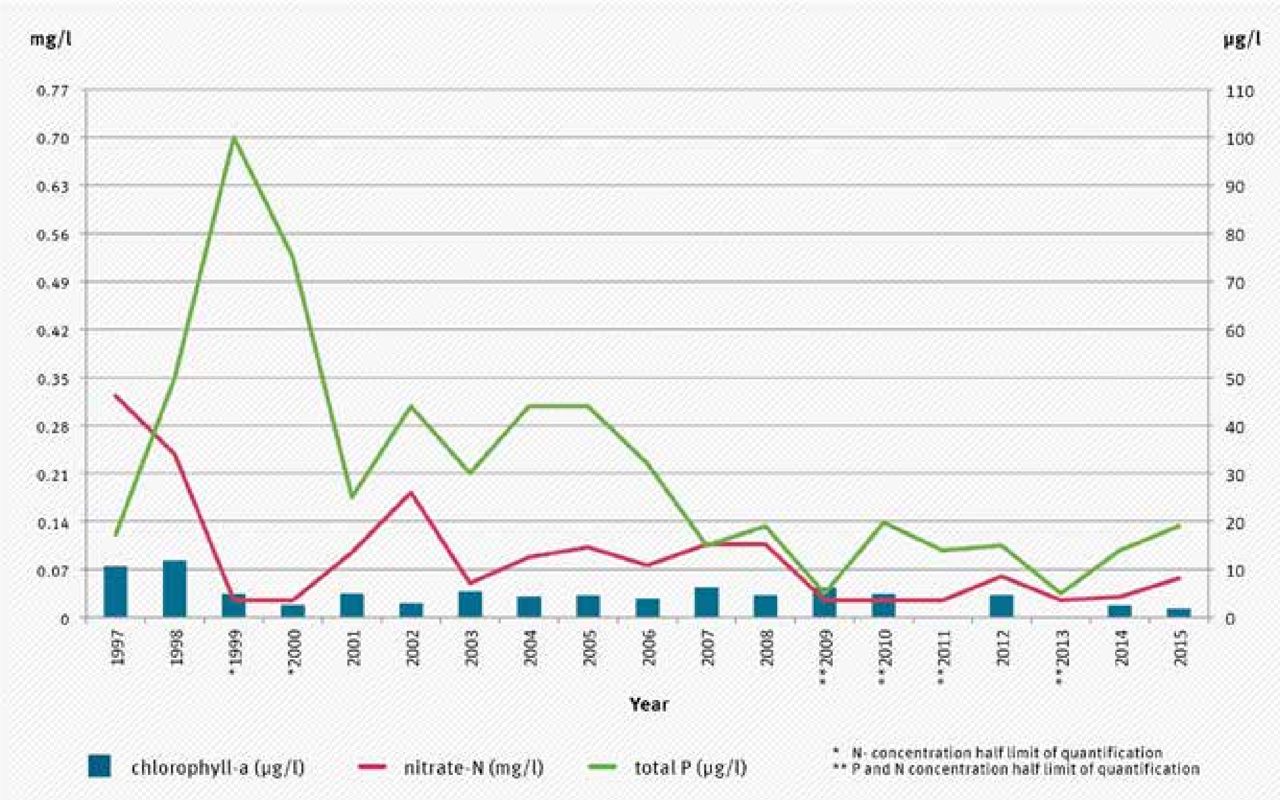
Schweriner See (annual means 1998–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Mecklenburg-Western Pomerania State Agency for Environment, Nature Conservation and Geology

Figure 39

Müritz (annual means 1997–2015, chlorophyll-a, nitrate-N and phosphorus)



Source: German Environment Agency based on data supplied by the Mecklenburg-Western Pomerania State Agency for Environment, Nature Conservation and Geology

Table 24

Trophic assessment of selected lakes in Germany

Trophic level *									
Lake	Reference	1990	1995	1996	1997	1998	1999	2000	2001
Ammersee	Oligotrophic	m	m	m	m	m	m	m	m
Arendsee	Oligotrophic	–	–	e1	e1	e1	e1	e1	e1
Lake Constanze	Oligotrophic	m	m	m	m	m	m	m	m
Brombachsee	Oligotrophic	–	–	–	–	–	–	m	m
Chiemsee	Oligotrophic	e1	m	m	m	m	m	m	o
Dobersdorfer See	Mesotrophic	e2	–	–	–	–	p1	e2	e2
Edersee Reservoir	Oligotrophic	–	–	–	–	–	–	m	m
Goitzschesee	Oligotrophic	–	–	–	–	–	–	–	–
Großer Müggelsee	Mesotrophic	p1	e1	e1	e1	e2	e2	e1	e2
Großer Plöner See	Oligotrophic	–	–	–	–	e1	e1	m	e1
Kochelsee	Oligotrophic	–	–	–	–	–	–	o	m
Königssee	Oligotrophic	–	–	–	–	–	–	o	–
Kummerower See	Mesotrophic	–	–	–	–	e1	e2	e2	e1
Laacher See	Oligotrophic	e1	e1	e1	e1	e1	e1	–	–
Langbürgner See	Oligotrophic	–	–	–	–	–	–	–	–
Muldestausee	Mesotrophic	–	–	–	–	–	–	–	–
Müritz (Outer Müritz)	Mesotrophic	–	–	–	m	e1	m	m	m
Müritz (Inner Müritz)	Mesotrophic	–	–	–	m	e1	m	m	m
Upper Havel	Weakly eutrophic	–	–	–	–	–	–	–	–
Ostersee	Oligotrophic	–	–	–	–	–	–	–	m
Plauer See	Mesotrophic	–	–	–	e1	m	m	m	m
Rappbode Reservoir	Oligotrophic	–	–	–	–	–	–	–	–
Sacrower See	Mesotrophic	–	e1	e1	e1	e1	e1	e2	e1
Scharmützelsee	Mesotrophic	–	e2	e2	e2	e2	e1	m	e1
Schweriner See (Outer Lake)	Mesotrophic	–	–	–	–	e1	e1	p1	e1
Schweriner See (Inner Lake)	Mesotrophic	–	–	–	–	e1	e1	e1	e1
Staffelsee	Oligotrophic	–	–	–	–	–	–	m	m
Starnberger See	Oligotrophic	m	m	m	m	m	m	m	o
Stechlinsee	Oligotrophic			o	o	o	o	o	o
Steinhuder Meer	Weakly eutrophic	p2	p2	p2	p2	p2	e2	e2	e1
Tegernsee	Oligotrophic	–	–	–	–	–	–	o	–
Unterbacher See	Mesotrophic	–	–	–	e1	e1	e1	e1	e1
Walchensee	Oligotrophic	–	–	–	–	–	–	o	o
Wörthsee	Oligotrophic	–	–	–	–	–	–	o	m
Zeuthener See	Weakly eutrophic	–	–	–	–	–	–	e2	e2

* According to LAWA 1999

2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
m	m	m	m	m	m	m	m	m	m	o	o	o
e1	e2	e2	e2	e2	e2	e1	e2	e1	e1	–	–	–
m	m	m	m	m	m	m	m	m	m	o	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	o	m	m	m	m	m	m	m	m	–	o	–
p1	e2	e2	e2	e2	e2	–	–	–	–	–	–	–
m	m	m	m	e1	e1	e1	m	m	m	m	o	m
–	–	–	–	–	–	m	m	o	o	–	–	–
e1	e2	e1	e2	e1	e1	e1	e1	e1	e1	–	–	–
e1	m	m	m	m	m	m	–	–	–	–	–	–
–	m	–	–	–	o	–	–	–	–	–	o	–
–	–	–	–	–	–	–	–	–	–	–	–	–
p1	e2	e2	e2	e2	e2	–	–	–	–	e2	e2	e1
–	–	–	m	–	–	m	–	m	m	m	–	–
–	–	–	o	–	–	–	–	–	–	o	–	–
e2	e2	e1	e2	e1	m	e1	m	m	m	–	–	–
m	m	m	m	m	m	m	–	–	–	m	–	e1
m	m	m	m	m	m	m	–	–	–	m	–	m
–	–	–	–	e2	e2	e2	e2	e2	e2	–	–	–
–	–	o	–	–	–	m	–	–	–	–	–	o
m	m	m	m	m	m	m	–	–	–	m	–	m
e1	e1	m	m	m	m	m	m	m	m	–	–	–
e1	e2	e1	e1	e1	e1	e1	–	–	–	–	–	–
e2	m	m	m	m	m	m	–	–	–	–	m	m
e2	e2	e2	e1	e1	e1	e1	–	–	–	e1	e1	m
e2	e2	e2	e1	e1	e1	e1	–	–	–	e2	e2	e2
–	–	m	–	–	m	–	–	m	m	–	o	–
m	m	o	o	m	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	–	–	–	–	m	–
e1	p2	p1	–	–	–	–	–	–	–	e2	e1	e2
–	–	–	–	–	–	o	–	–	–	–	–	o
e1	e1	e1	e1	e1	e1	e1	–	–	–	–	–	–
–	o	–	–	o	–	o	–	–	–	–	–	o
m	m	–	o	–	–	o	–	–	–	–	–	o
e2	e2	e2	e2	e2	e2	e2	e2	e2	e2	–	–	–

ACTUAL status

Referenzzustand *	Oligotrophic (o)	Mesotrophic (m)	Weakly eutrophic (e1)	Highly eutrophic (e2)	Weakly polytrophic (p1)	Highly polytrophic (p2)	Hyper-trophic (h)
Oligotrophic							
Mesotrophic							
Weakly eutrophic							
Highly eutrophic							
Weakly polytrophic							

* According to LAWA 1999

Source: German Environment Agency from data supplied by LAWA

Owing to the morphology of their lake basin (very deep, steep sides, high hypolimnion/ epilimnion ratio), many **former mine lakes** offer favourable parameters for the development of clear, low-nutrient lakes. For the transition from empty excavation to filled mining lake, it is usually preferable to flood with external water from rivers rather than allowing them to fill with rising groundwater. Rapid flooding reduces the risk of land-slips, and especially of soil liquefaction, at the sides of the mining lake, and the water deficit in the whole of the post-lignite mining landscape, and especially the deficit in the groundwater balance (cf. chapter 3.2), should be equalised more quickly by flooding the excavations with surface water. The quality requirements governing the water used to flood the lake should prevent excessive eutrophication. LAWA in collaboration with the German Environment Agency has drawn up recommendations for quality requirements for mining lakes and their in-flows and outflows (LAWA brochure "Tagebaurestseen – Anforderungen an die Wasserqualität", 2001). A status description of selected mining lakes has been compiled in the brochure "Übersicht zur ökologischen Situation ausgewählter Tagebauseen des Braunkohlebergbaus in Deutschland" (Nixdorf et al. 2016).

6.2.3 Ecological status

Among lakes in Germany with an area of more than 0.1 km² (of which there are almost 2,000), 863 are assessed under the mapping provisions of the Water Framework Directive (lakes with an area of more than 0.5 km²). As a result, to date 624 lake water bodies (74.3 %) have been assessed as natural, 105 (12.5 %) as heavily modified water bodies and 111 (13.2 %) as artificial water bodies (LAWA 2016b).

Among the natural lakes (Figure 40),

- 3 % are assessed as having a "high" ecological status,
- 18 % as "good",
- 35 % as "moderate"
- 26 % as "poor", and
- 9 % as "bad" (LAWA 2016b).

Among heavily modified lakes, the assessment is as follows (Figure 40):

- 24 lakes are assessed as "good and above"
- 36 as "moderate", and
- 33 as "poor" and
- 7 lakes as "bad" (LAWA 2016b).

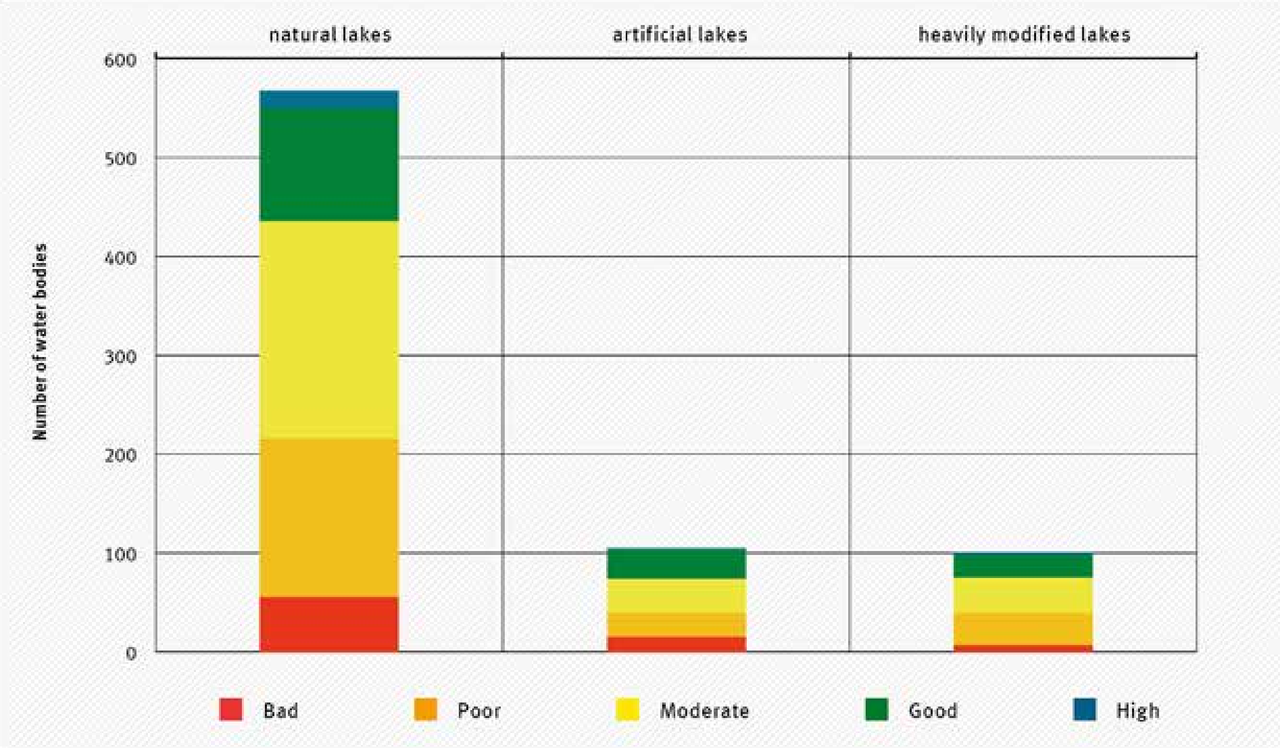
Artificial lakes are classed as "good and above" (31 lakes), "moderate" (34), "poor" (24) and "bad" (16) (Figure 40, LAWA 2016b).

Excessively high nutrient inputs are the main reason why lakes fall short of "good ecological status" or "good ecological potential". The Alpine and pre-Alpine lakes exhibit the best quality, with a good or even high status exhibited almost throughout. Among lakes in the North German lowlands, approximately one-third of the deep, stratified lakes (see chapter 6.1.1) exhibit a good or better status, but this is only true of around 10 % of the shallower, unstratified lakes (Figure 41).

The good and high ecological status of the pre-Alpine lakes is attributable to the early reduction of phosphorus concentrations, thanks to improved wastewater

Figure 40

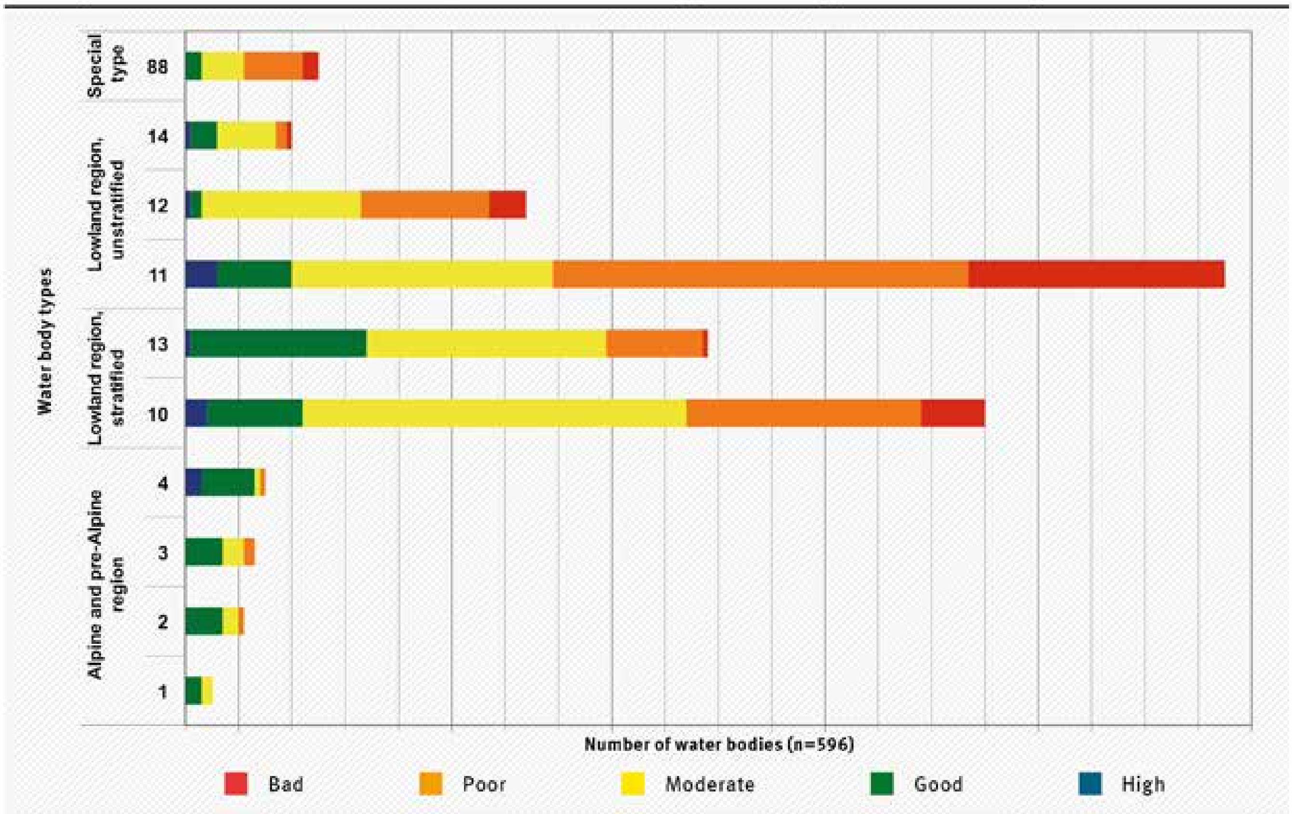
Ecological status of natural lakes (n=568) and ecological potential of artificial (n=105) and heavily modified (n=100) lake water bodies in Germany (number of water bodies not assessed: 68)



Source: German Environment Agency after LAWA 2016b

Figure 41

Ecological status of natural lakes, divided according to lake types in Germany



Source: German Environment Agency after LAWA 2016b

treatment technology and the installation of a perimeter sewage system in the mid-1970s. The comparatively shallow lakes of the North German lowlands, however, have large catchment areas generally characterised by agricultural use, and merely reducing nutrient emissions from point discharges alone is not enough. In the new Laender, where many of these shallow lakes are located, nutrient emissions were not reduced until the early 1990s when wastewater treatment technology was improved, and the trophic levels of most lakes tend to respond to such nutrient reductions with a delay.

The ecological status of lakes was generally determined on the basis of phytoplankton and macrophytes or phytobenthos (see chapter 6.1.2).

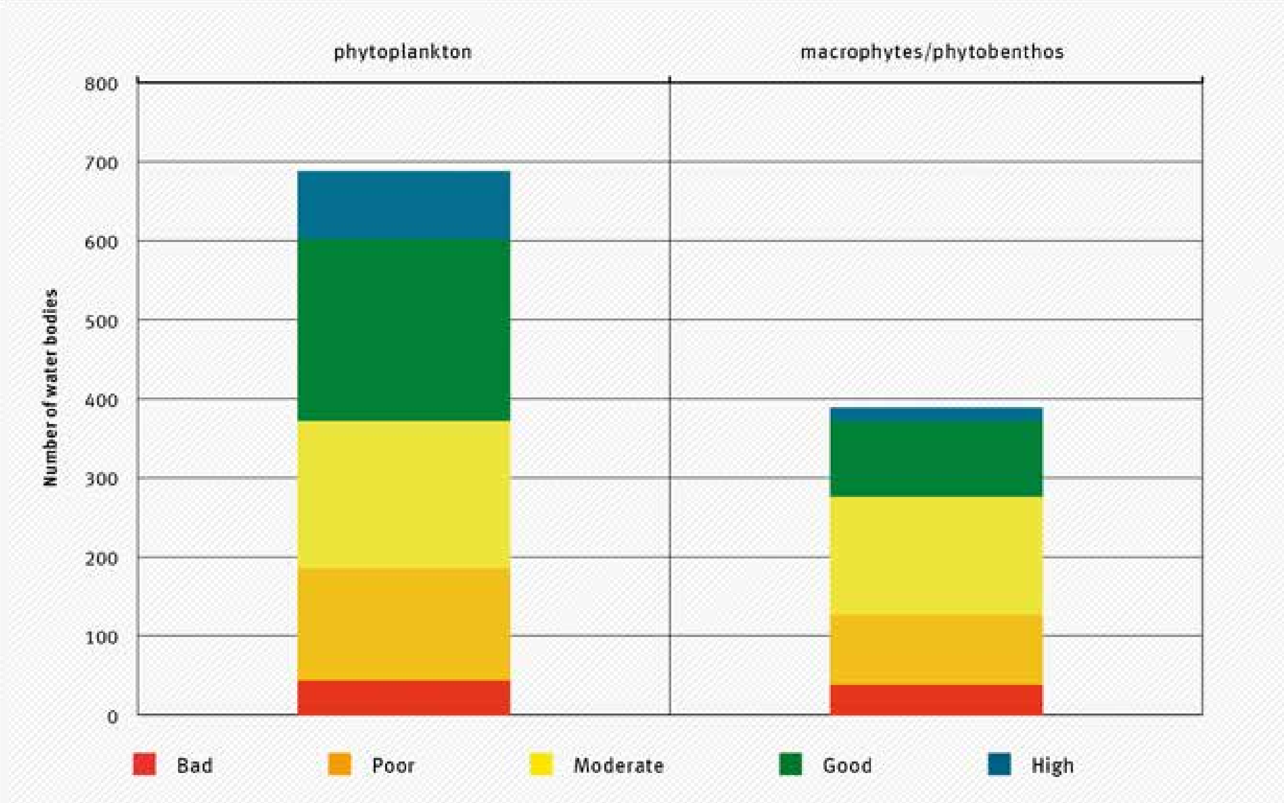
The phytoplankton community is particularly responsive to nutrient pollution levels in lakes. For half of natural lakes, the status of phytoplankton was assessed as "good" or "high" (Figure 42). By contrast, for macrophytes, only 37 % of lakes achieved a similar assessment. The inferior macrophyte status could be attributable to the higher nutrient and pollutant levels in the lake sediment compared with the open waters, together with structural-morphological pressures, to which macrophytes respond sensitively. Furthermore, aquatic plants do not naturally re-establish themselves until phytoplankton biomass has been reduced over a period of several years.

6.2.4 Chemical status

No German lake achieves a "good" chemical status, due to the pollution situation with mercury in biota (LAWA 2016b). The available measurement results for lakes have likewise been transferred to all water bodies (see also chapter 5.2.8 in the brochure "The Water Framework Directive – The status of German waters 2015"). Measurement results in biota from Mecklenburg Western Pomerania for fish from all the lakes analysed indicate instances of total brominated diphenyl ether being exceeded.

Figure 42

Ecological status of the biological quality elements macrophytes/phytobenthos and phytoplankton for natural lake water bodies



Source: German Environment Agency after LAWA 2016b

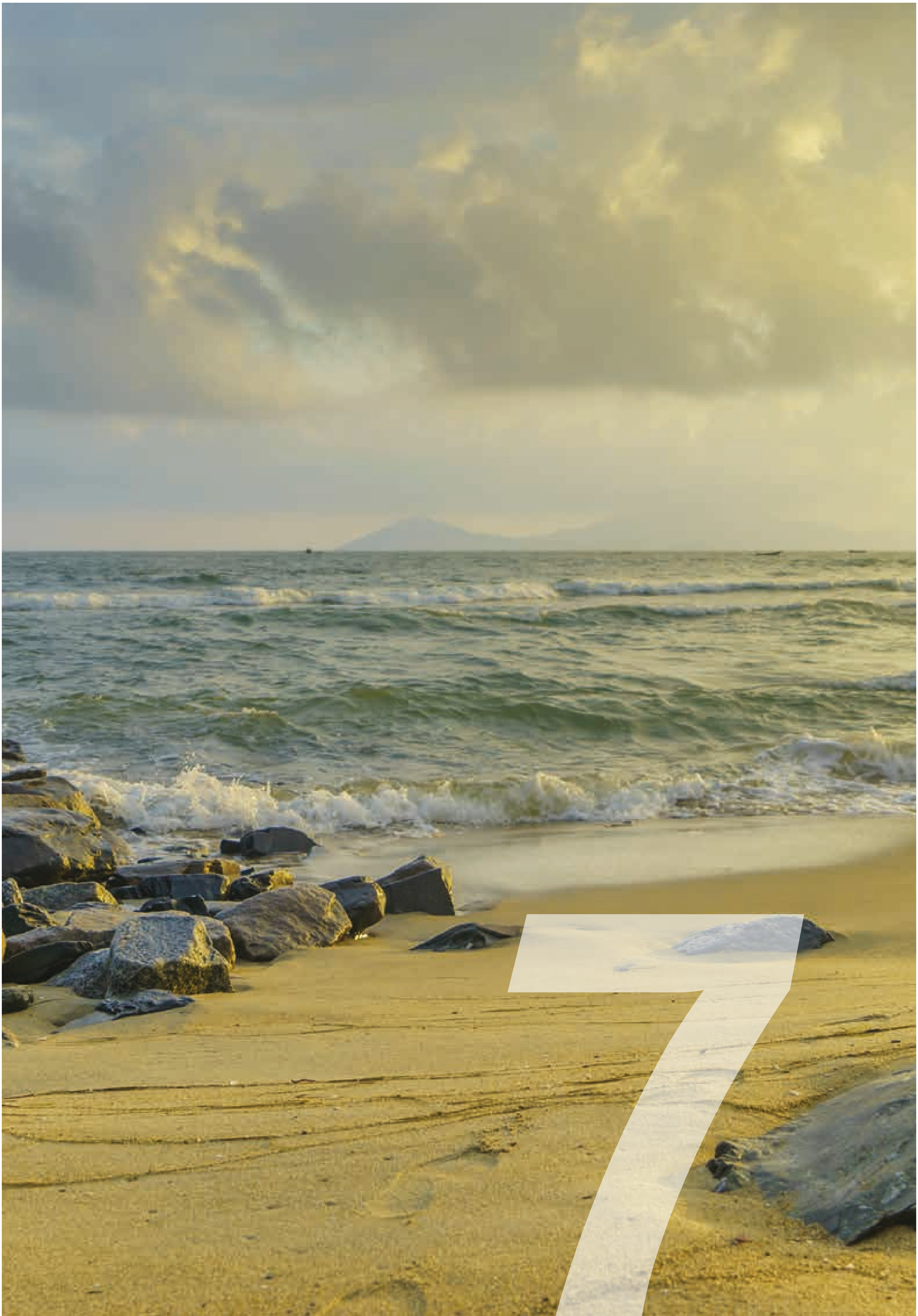
Table 25

Results of pollutant measurements in fish from the lakes of Mecklenburg Western Pomerania, 2013–2015

Name of substance	Concentration range (min – max) in µg/kg (wet weight) *	Biota EQS in µg/kg (wet weight)
Mercury	38–119	20
Dicofol	‹0.02	33
Brominated diphenyl ether	0.028–0.137	0.0085
Hexabromocyclododecane	‹0.2–0.17	167
Hexachlorobenzene	0.023–0.054	10
Hexachlorobutadiene	‹0.02	55
Perfluorooctanesulfonic acid	‹2.0–3.14	9.1

* Fish species analysed: Perch, roach, bream

Source: LUNG 2016


7

7 Transitional, coastal and marine waters

7.1 Basis for assessment

Under the EU Water Framework Directive, the ecological status of transitional and coastal waters (up to 1 nautical mile) is assessed on the basis of biological, hydromorphological, chemical and general physico-chemical quality elements (chapter 4.2.1). Additionally, the Habitats Directive assesses selected rare species and habitat types and defines designated protected areas for them in coastal and marine waters. These European regulations were supplemented in 2008 with the EU Marine Strategy Framework Directive (MSFD), requiring Member States to undertake an initial assessment of coastal and marine waters by mid-2012, and a follow-up assessment every six years. The MSFD stipulates that Member States coordinate with one another within the regional sea conventions when implementing the MSFD. Prior to the MSFD's adoption, the regional sea conventions (Convention for the Protection of the Marine Environment of the North-East Atlantic, OSPAR and the Convention on the Protection of the Marine Environment of the Baltic Sea Area, HELCOM) were already assessing biological parameters and the overall ecological status of the North and Baltic Seas. Given the aforementioned new role of the regional sea conventions and the fact that EU Water Framework Directive, EU Marine Strategy Framework Directive, Habitats Directive and regional sea conventions overlap in their application areas, it is vital to develop harmonised assessment methods and to review existing procedures for their general applicability.

7.1.1 EU Water Framework Directive (WFD)

The WFD calls for an assessment of the ecological and chemical status of the transitional and coastal waters of the North and Baltic Seas.

Types of transitional and coastal waters

Transitional waters in northern Europe are river estuaries; at national level, they are assigned to one of two types: Type T1: Transitional waters Elbe, Weser, Ems; type T2: transitional waters Eider. For Germany's Baltic Sea coast transitional waters have not been designated.

Coastal waters are characterised according to the factors of geographical latitude, geographical longitude, salt content and depth, together with the optional physico-chemical factors current velocity, wave exposure, water temperature and its fluctuation range, composition of the substrate, and turbidity (secchi depth). Along the German Baltic Sea coast, four main types B1 to B4 (Figure 43) and six sub-types (not shown on the map), delineated by salt content, are distinguished. Germany's North Sea coast is divided into five types of coastal waters (Types N1 to N5), with salt content and sediment composition used as typology criteria (Figure 43). As a general rule, the Wadden Sea coast is demarcated from the more exposed outer coasts. The coastal waters around Helgoland have been designated a separate type. The types of transitional and coastal waters are listed in Annex 1 to the Ordinance on Surface Waters (Oberflächengewässerverordnung, OGewV).

Biological quality elements

The basis for assessment has already been outlined in detail in chapter 4.2.1, so the following account will focus on selected aspects of the ecological assessment of coastal waters only. The WFD assesses ecological status on the basis of four biological quality elements. The assessment methods used for biological quality elements are set out in Annex 6 to the Ordinance on Surface Waters.

Hydromorphological quality elements

Annex V of the Water Framework Directive lists "morphological conditions" and "tidal regime" as hydromorphological quality elements for classifying the ecological status of transitional and coastal waters. These quality elements have a supporting effect in the classification of ecological status/ecological potential, by helping to determine the reference conditions (high status or maximum ecological potential) (see chapter 4.2.1).

General physico-chemical quality elements

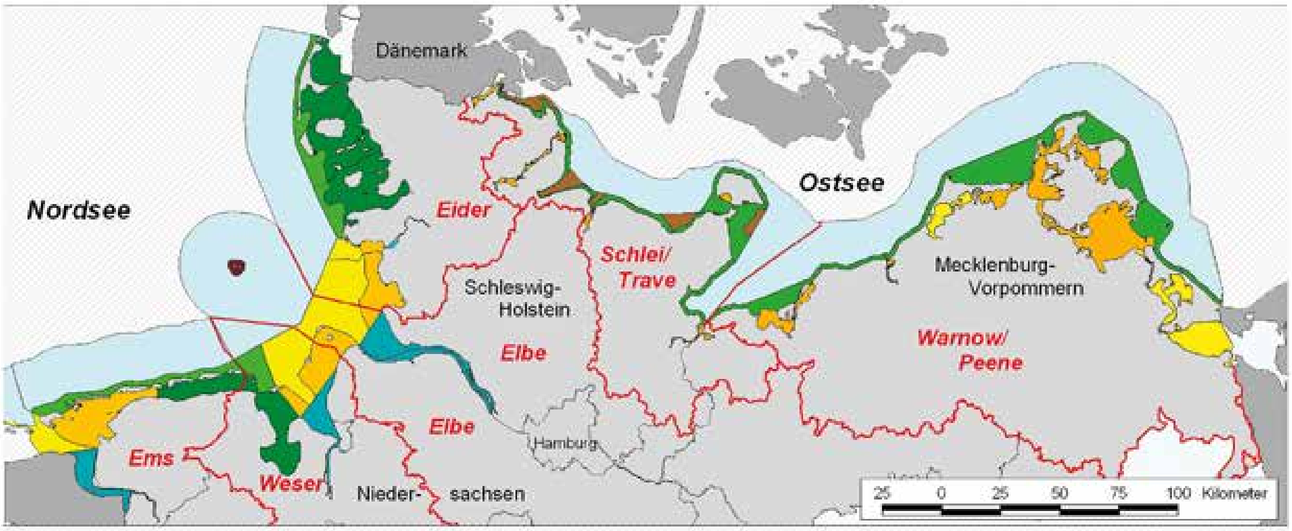
Annex 7 to the Ordinance on Surface Waters specifies type-specific concentration ranges for salinity, total nitrogen, inorganic dissolved nitrogen, nitrate nitrogen, total phosphorus and orthophosphate phosphorus, which characterise "good" or "high" status, as reference conditions for the general physico-chemical quality elements (cf. chapter 4.2.1).

Target management values

For the first time, the 2016 amendment to the Ordinance

Figure 43

Germany's types of transitional and coastal waters pursuant to the EU WFD



COASTAL WATERS

NORTH SEA

- Coastal waters
- N1 Euhaline open coastal waters
- N2 Euhaline Wadden Sea
- N3 Polyhaline open coastal waters
- N4 Polyhaline Wadden Sea
- N5 Euhaline rocky coastal waters around Helgoland

BALTIC SEA

- Coastal waters
- B1 Oligohaline inner coastal waters
- B2 Mesohaline inner coastal waters
- B3 Mesohaline open coastal waters
- B4 Meso-polyhaline open coastal waters, seasonally stratified

TRANSITIONAL WATERS

NORTH SEA

- T1 Elbe, Weser, Ems
- T2 Eider

Source: German Working Group on water issues of the Laender and the Federal Government (LAWA)

on Surface Waters specifies target management values for total nitrogen (annual means) for rivers that discharge into the North and Baltic Seas. These values are adjusted to marine protection targets, and apply at the transition from limnic to marine waters at the relevant freshwater monitoring sites. For the North Sea, 2.8 mg/l total nitrogen has been set as the target management value, and for the Baltic Sea 2.6 mg/l. From these target values, it is possible to derive inland targets for nitrogen concentrations valid for the other rivers of the catchment. A corresponding concept by LAWA with enforceable, regionalised reduction targets for total nitrogen is already available (Figure 44, LAWA 2014a).

The management targets for eutrophication are designed to allow the North and Baltic Seas to achieve good status. At the same time, in the Baltic Sea, the target value will help to achieve the nutrient reduction targets formulated in the HELCOM Baltic Sea Action Plan. For phosphorus, the threshold values for good status in rivers set out in the Ordinance on Surface Waters are thought to be adequate for marine protection targets as well (Annex 7 to the Ordinance on Surface Waters).

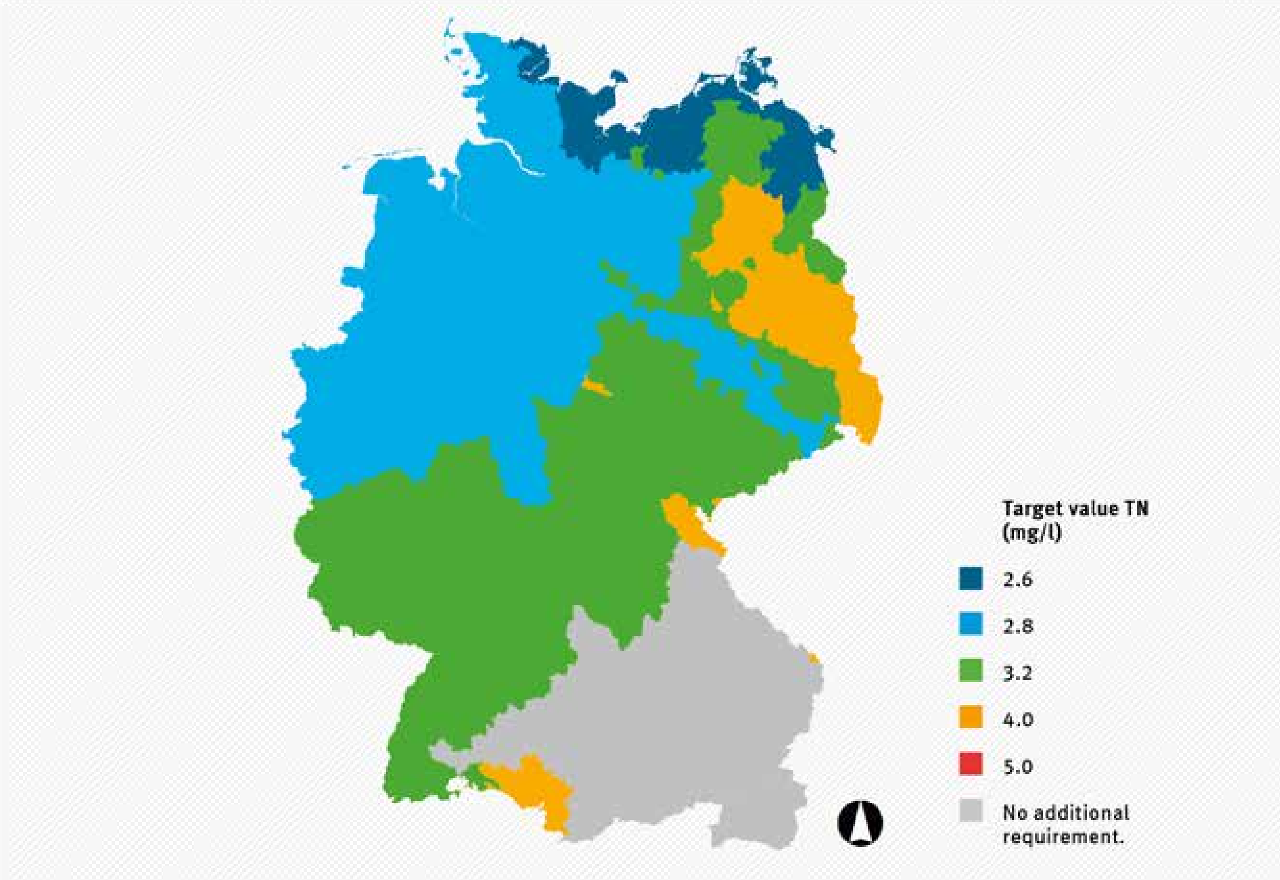
7.1.2 EU Marine Strategy Framework Directive (MSFD)

The Marine Strategy Framework Directive requires the assessment of coastal waters and marine waters in the Exclusive Economic Zone (EEZ). In order to record and assess "good environmental status" for Germany's marine regions, 11 descriptors (see Table 26) were outlined and more precisely defined with the aid of characteristics (Annex III, Table 16 of the MSFD) and pressures/ impacts (Annex III, Table 19 of the MSFD) listed in the Marine Strategy Framework Directive: One descriptor refers to marine biodiversity (D1), another one to marine food webs (D4), a third one to the integrity of the seafloor (D6, habitat), and eight more to anthropogenic pressures resulting from specific uses. A decision by the EU Commission defines the criteria and methodological standards (EU-COM 2010/477/EU) as the basis for a har-

Figure 44

For the marine ecology vital maximum mean nitrogen concentrations inland per year, extrapolated with due regard to retention for planning units

(North Sea: 2.8 mg/l TN; Baltic Sea: 2.6 mg/l TN)



Source: LAWA 2014a

monised European-wide assessment of "good environmental status", and specifies a total of 56 indicators. As the majority of these indicators were not operationalised in a timely manner, the initial assessment of Germany's marine waters in 2012 was based primarily on existing assessments under the Water Framework Directive, the Habitats Directive, and OSPAR and HELCOM. In November 2016, a revised decision by the EU Commission was presented, outlining the requirements of the Marine Strategy Framework in more detail, reducing the number of indicators, and defining methodological standards (assessment rules) alongside primary and secondary criteria (indicators). The revised Commission Decision (Commission Decision 2017/848/EU) lays the foundations for improved regional coherence when implementing the MSFD.

Whereas sophisticated assessment methods already exist for certain pressures (such as eutrophication, pollutants and a few aspects of fishing) and their impacts on organisms and populations are already well-documented, for other less investigated factors such as noise pollution of the oceans and inputs of litter, suitable assessment methods have been developed only in recent years. Indicators and assessment approaches must also be developed for marine biodiversity (particularly for assessing benthos, plankton, fish, sea birds and marine mammals). This development work is being carried out at EU level and within the framework of OSPAR and HELCOM. The first newly developed indicators and assessment methods will be used for the follow-up assessment in 2018, as required by the Marine Strategy Framework Directive.

OSPAR and HELCOM serve as basis for EU countries bordering the North-East Atlantic and the Baltic Sea for implementing the Marine Strategy Framework Directive. They holistically and thematically assess the environmental status in the regions of the Convention. The Marine Strategy Framework Directive builds on these harmonised procedures. With its Baltic Sea Action Plan, HELCOM pursues the vision of a “healthy Baltic Sea environment with balanced biological elements” based on a hierarchical strategy comprising four segments: eutrophication, hazardous substances, biodiversity and maritime activities. There are a number of ecological objectives assigned to each of these areas, achievement of which is assessed according to a series of measured parameters.

In 2010, HELCOM published its first Holistic Assessment (HELCOM HOLAS) of the marine environment of the Baltic Sea, with data from the period 2003–2007. The assessment is based on the ecosystem approach and considers a number of relevant pressures and their impacts on marine organisms, considering not only the current status of the ecosystem but trends as well. HOLAS II, the follow-up assessment in 2017, is based on data from the period 2011–2015. The subject areas have been retained, but new indicators were developed for the MSFD, and the assessment tools are currently being amended in line with MSFD requirements.

At the 2010 Ministerial Conference, OSPAR adopted thematic strategies for the subject areas of biodiversity, eutrophication, hazardous substances, radioactive substances, and offshore oil and gas extraction. The assessment systems for eutrophication, hazardous substances and radioactive substances are well developed, whereas assessment and monitoring of biodiversity is

still in its infancy. The assessment results are published in regular Quality Status Reports (1987, 1993, 2010), the next being scheduled for 2021. However, an “Intermediate Assessment” is scheduled for publication in 2017, which can be used by the OSPAR Contracting Parties as the basis for a follow-up assessment as required by the MSFD in 2018.

As previously mentioned, the Marine Strategy Framework Directive’s entry into force radically transformed the role of the regional sea conventions. HELCOM and OSPAR increasingly function as coordination platforms for the implementation of the Marine Strategy Framework Directive, and their work currently focuses on the development of regional core indicators, used, for example, in the Baltic Sea to implement both the Baltic Sea Action Plan and the Marine Strategy Framework Directive.

Assessment basis for descriptor 5: Eutrophication

Small highland river close to the source
Source: Stephan Naumann

For assessment purposes, OSPAR has developed the “Common Procedure for the Identification of the Eutrophication Status of the Maritime Area” (COMP), which also applies to MSFD descriptor 5: “Eutrophication”. At the same time, it is one of the main elements of OSPAR’s 2010 strategy to tackle eutrophication, and is intended to restore a healthy marine environment devoid of eutrophication by 2020 at the latest. This target has not yet been met, despite a significant reduction in nutrient inputs via the rivers that discharge into the North Sea.

The designation procedure is comprised of assessment criteria based on the degree of nutrient enrichment as well as direct and indirect eutrophication effects (see Table 27), which permit classification into problem areas (PA), potential problem areas (PPA) and non-problem areas (NPA). In 2012, this procedure was adapted to the requirements of the Marine Strategy Framework Directive. HELCOM has refined the OSPAR assessment method and applies it regularly to the Baltic Sea.

Other assessment methods used to assess eutrophication under descriptor 5 of the Marine Strategy Framework Directive are outlined in chapter 7.2.1.

Table 26

Overview of descriptors of good environmental status (EU Marine Strategy Framework Directive)

Qualitative descriptors for determining good environmental status
1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.
2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.
3. Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
4. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.
5. Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.
6. Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.
7. Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
8. Concentrations of contaminants are at levels not giving rise to pollution effects.
9. Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.
10. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
11. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Source: Annex I to the Marine EU Strategy Framework Directive MSRL

Assessment basis for descriptor 8: Contaminants in the marine environment

The Marine Strategy Framework Directive defines Good Environmental Status (GES) for contaminants in the marine environment (descriptor 8) based on selected pollution indicators. The indicators for assessment of the marine regions are coordinated under OSPAR and HELCOM. The pollution indicators are closely aligned with the substances classed as priority or priority hazardous substances under the Water Framework Directive. The Environmental Quality Standards (EQS) of the Water Framework Directive are used as the main basis for assessment (see chapters 4.2.2 and 4.2.3). The EQS under the Water Framework Directive are primarily derived for the "water" matrix, while assessment of pollutant levels in the marine environment mainly uses the "biota" and "sediment" matrices. Consequently, if there is no suitable EQS available, the OSPAR assessment thresholds are used to assess the North and Baltic Seas (Table 28).

7.1.3 Marine monitoring and central data storage by the Federation

Between 1997 and 2012, the competent Federal Government departments and the relevant departments in Bremen, Mecklenburg-Western Pomerania, Lower Saxony and Schleswig-Holstein collaborated on the German Marine Monitoring Programme (GMMP). Laender and Federation made an administrative agreement on the protection of the marine environment (Verwaltungsabkommen, VerwAbk 2012) to implement the MSFD. Cooperation between Federation and the coastal Laender for monitoring the marine environment is ongoing, supplemented by the additional requirements of the Marine Strategy Framework Directive. This cooperation is supposed to meet national, European and international obligations with respect to the protection of the marine environment in an efficient manner.

Table 27

Criteria for assessing the physico-chemical and biological parameters of eutrophication in accordance with the OSPAR "Common Procedure"

Category	Assessment parameter	
I	Degree of nutrient enrichment	
	1	Riverine inputs and direct discharges Elevated inputs and/or rising trends (compared with previous years)
	2	Nutrient concentrations Elevated levels (defined as concentration > 50 % above salinity-related and/or region-specific background concentrations) of winter DIN and/or DIP and total nitrogen and phosphorus
	3	Winter N/P ratio (Redfield N/P = 16) Elevated in relation to natural Redfield ratio (> 50 % deviation: > 25)
II	Direct effects of nutrient enrichment (during growing season)	
	1	Chlorophyll a concentration Elevated maximum and mean levels or 90 percentile (defined as concentration > 50 % of regional (e.g. open sea) background concentrations)
	2	Regional/area-specific phytoplankton indicator species Elevated densities (and extended duration of blooms)
	3	Macrophytes including macroalgae (regional-specific) Shifts from long-lived to short-lived (nuisance) species (e.g. Ulva) Elevated density, especially of opportunistic green algae
III	Indirect effects of nutrient enrichment (during growing season)	
	1	Oxygen deficiency Decreased levels (< 2 mg/l: acute toxicity, 4–6 mg/l: deficiency)
	2	Changes/kills among zoobenthos and fish Death (caused by oxygen deficiency and/or toxic algae) Long-term changes in zoobenthos (biomass and/or species composition)
	3	Organic carbon/organic matter Elevated levels (in relation to oxygen deficiency, relevant in sedimentation areas)
IV	Other possible effects of nutrient enrichment (during growing season)	
	1	Algal toxins (occurrence of DSP / PSP in mussels) Incidence (phytoplankton indicator species)

DSP = Diarrhetic Shellfish Poisoning
PSP = Paralytic Shellfish Poisoning

Source: OSPAR 2013

Table 28

OSPAR assessment criteria for the contamination of common mussels with selected contaminants

Name of substance	Background Assessment Criteria* (BAC) Common mussel µg/kg dry weight	Environmental Assessment Criteria** (EAC) Common mussel µg/kg dry weight
Lead	1,300	
Cadmium	960	
Tributyl tin		12

* Background Assessment Criteria (BAC) correspond to concentration levels found at unpolluted sites in the North-East Atlantic.
** Environmental Assessment Criteria (EAC), like environmental quality standards, are ecotoxicologically derived concentration thresholds, below which no chronic effects on marine organisms are anticipated.

Source: OSPAR 2009a

The individual measurement programmes and an overview of the individual legal sources are outlined in the Monitoring Manual (GMMP 2016). The data provides the basis for the evaluations in chapter 7.21. The Monitoring Manual is currently being revised to meet the requirements of the Marine Strategy Framework Directive. Besides the monitoring of the marine environment, it is necessary to collect data on pressure- and measure-related indicators for this purpose, too.

Data on nutrient emissions into the North and Baltic Seas is based on the measurement programmes of the coastal Laender and is fed into the databases of the regional sea conventions HELCOM and OSPAR (HELCOM PLC and OSPAR RID).

Assessments of the accumulation of heavy metals in biota (chapter 7.2.2.1) and organic pollutants in biota (chapter 7.2.2.2) in the North and Baltic Seas is based solely on data from the Environmental Specimen Bank (Umweltprobenbank, UPB). The UPB has been analysing pollutants in marine fauna and flora on a regular basis since 1986. In the North Sea, the sampling areas of Sylt-Römö-Watt and Meldorf Bight are located in Schleswig-Holstein, and that of the Jade Estuary in Lower Saxony. In the Baltic Sea, the sampling area is the Western Pomerania Lagoon Area National Park (Nationalpark Vorpommersche Boddenlandschaft) (UPB 2016).

7.1.4 Quality assurance in marine monitoring

The participating laboratories in the GMMP for the marine environment of the North and Baltic Seas are responsible for the quality and comparability of the analytical results. They are assisted by the Quality Assurance Panel of the GMMP, assigned to the German Environment Agency, independent and not involved in the monitoring itself. The introduction of quality management systems according to DIN EN ISO/IEC 17025 throughout all laboratories is a key measure for ensuring the quality of the monitoring results. To this end, the Quality Assurance Panel provides a sample quality management manual tailored to the specific requirements of the GMMP, and sample standard operating procedures for selected biological methods.

The use of reference materials (RM) is an important measure of internal quality assurance at the laboratories. These are chemical substances of a defined purity or stable, homogeneous materials that are similar to the samples under analysis and whose contents of selected pollutants are known. They may be used to calibrate a measuring instrument or to test the applicability of a measurement method for a certain monitoring task (validation).

Laboratory intercomparisons are the most important element of external quality assurance. For physico-chemical measurements, QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe) offers ring tests for many of the parameters relevant to marine monitoring. Participants in a ring test receive identical samples of sea water, sediment, fish or mussels and are required to quantify the nutrient, heavy metal or organic pollutant contents. The participants' results are then assessed for their comparability.

Laboratory intercomparisons are also feasible and useful for biological parameters, by helping to identify any deficits in the quality of monitoring data. For example, a ring test might be used to compare the taxonomic expertise of participating laboratories in identifying relevant groups of organisms, and to ascertain their counting accuracy. At the same time, it provides an indication of assessment-relevant groups of organisms whose taxonomic classification is difficult and consequently may lead to inaccurate assessments.

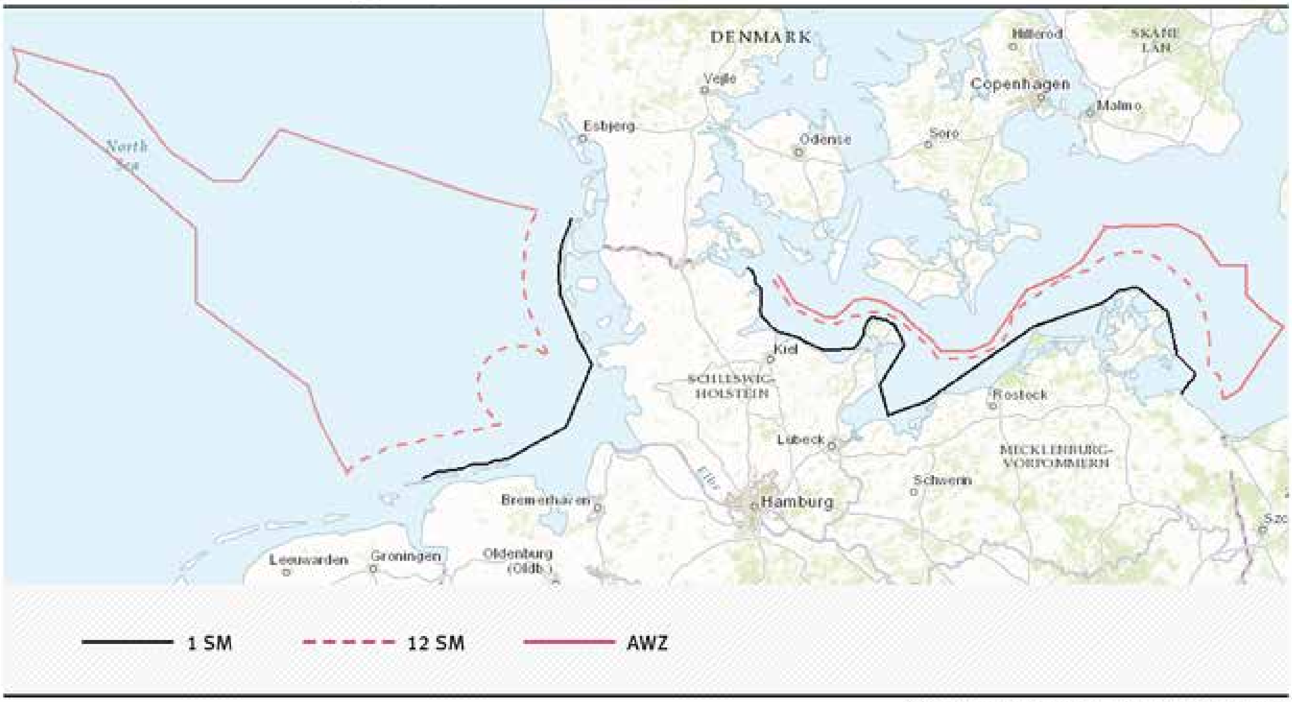
7.2 Status assessment

7.2.1 Eutrophication

Eutrophication is due to the accumulation of nutrients (phosphorus, nitrogen) in water as a result of human activities. This leads to the accelerated growth of monocellular algae (phytoplankton) and macrophytes (large, sessile algae and sea grass). Eutrophication changes the aquatic biotic communities and the quality of the water itself. Over-fertilisation may lead to increased algal growth, shifts in species composition and lack of oxygen due to the bacterial decomposition of dead algae. The lack of oxygen impairs other plants, benthic fauna and fish. This leads to the development of toxic hydrogen sulphide, and the nutrients released amplify the eutrophication effects. Atmospheric nitrogen emissions from agriculture, shipping, transport, power plants and industry also contribute to the eutrophication of the seas. After fishing, eutrophication is the second-biggest pressure on the North and Baltic Seas, and therefore plays a major role in marine protection.

Figure 45

German Marine Monitoring Programme GMMP



Source: German Federal Institute of Hydrology (BfG)

7.2.1.1 Eutrophication of the North Sea

Nutrient inputs

Nutrient inputs are ascertained both as direct loads transported in the rivers via measured substance concentrations and flow rates, and as balanced substance inputs from point and diffuse sources into the surface waters of the North Sea catchment area using the model approach (Modelling of Regionalized Emissions MoRE). Balancing with the MoRE approach disregards retention in the water bodies – in other words, the balanced inputs are higher than the calculated loads. The calculated nutrient loads at the mouths of the rivers Ems, Weser and Elbe are based on data series since 1980. In the case of the river Eider, data is only available from 1990 onwards. Among these rivers, the Elbe accounts for the largest portion of nutrient inputs into the North Sea. The current trend is characterised by a constant reduction in nutrient loads (Figures 46 and 47).

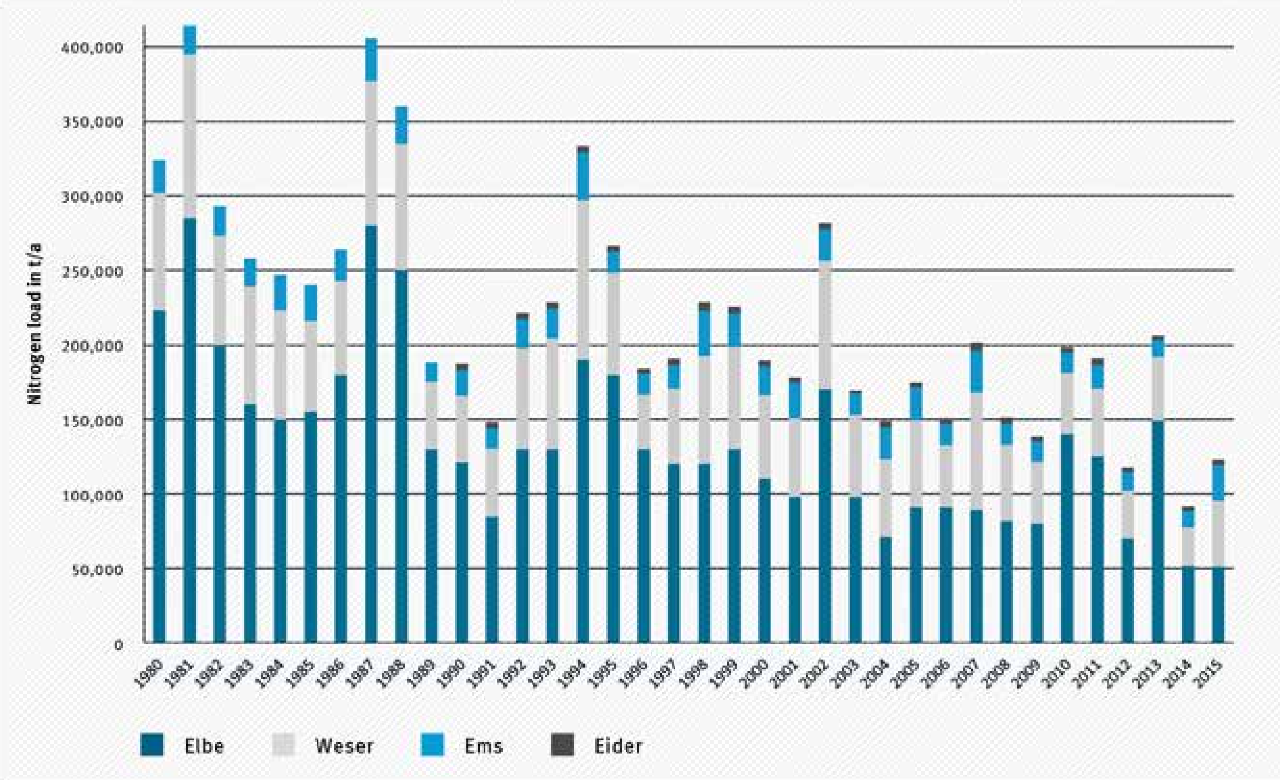
Depending on the water flow, phosphorus and nitrogen react distinctly. Unlike phosphorus compounds (high soil binding capacity), higher quantities of precipitation lead to increased leaching and run-off of nitrogen compounds from agricultural soils. Over the period 1990 to 2014, nitrogen loads in the river Elbe decreased by 43 %. The average reduction in phosphorus loads via the rivers Elbe, Weser and Ems was around 41 % during the period 1990 to 2014.

Between 1983–1987 and 2012–2014, nutrient inputs, modelled with MoRE, into the surface waters of the German North Sea catchment area were reduced by 50 %, from around 804,000 t/a to 353,400 t/a in the case of nitrogen, and by around 70 % from 67,200 t/a to 17,500 t/a in the case of phosphorus. Point sources are mainly responsible for the decrease in nitrogen inputs, whose share of total inputs decreased to around 20 % in 2012–2014 (Figure 48). 70 % of total nitrogen inputs originate from agriculture; 68 % thereof are inputs via groundwater, 22 % via drainage, 5 % via runoff from predominantly agricultural land, and 2 % each from atmospheric deposition and erosion.

The 74 % reduction in phosphorus inputs is likewise primarily attributable to reduced inputs from point sources (by 88 %). The huge reduction in phosphorus inputs from point sources meant that emissions from diffuse sources predominated in 2012–2014, accounting for approximately 65 %; around 48 % of these emissions are attributable to agriculture (groundwater, erosion, surface run-off and drainage) (Figure 49). By contrast, phosphorus inputs from diffuse sources decreased by 30 % in 2012–2014 compared with 1983–1987, due mainly to the halving of phosphorus inputs from urban

Figure 46

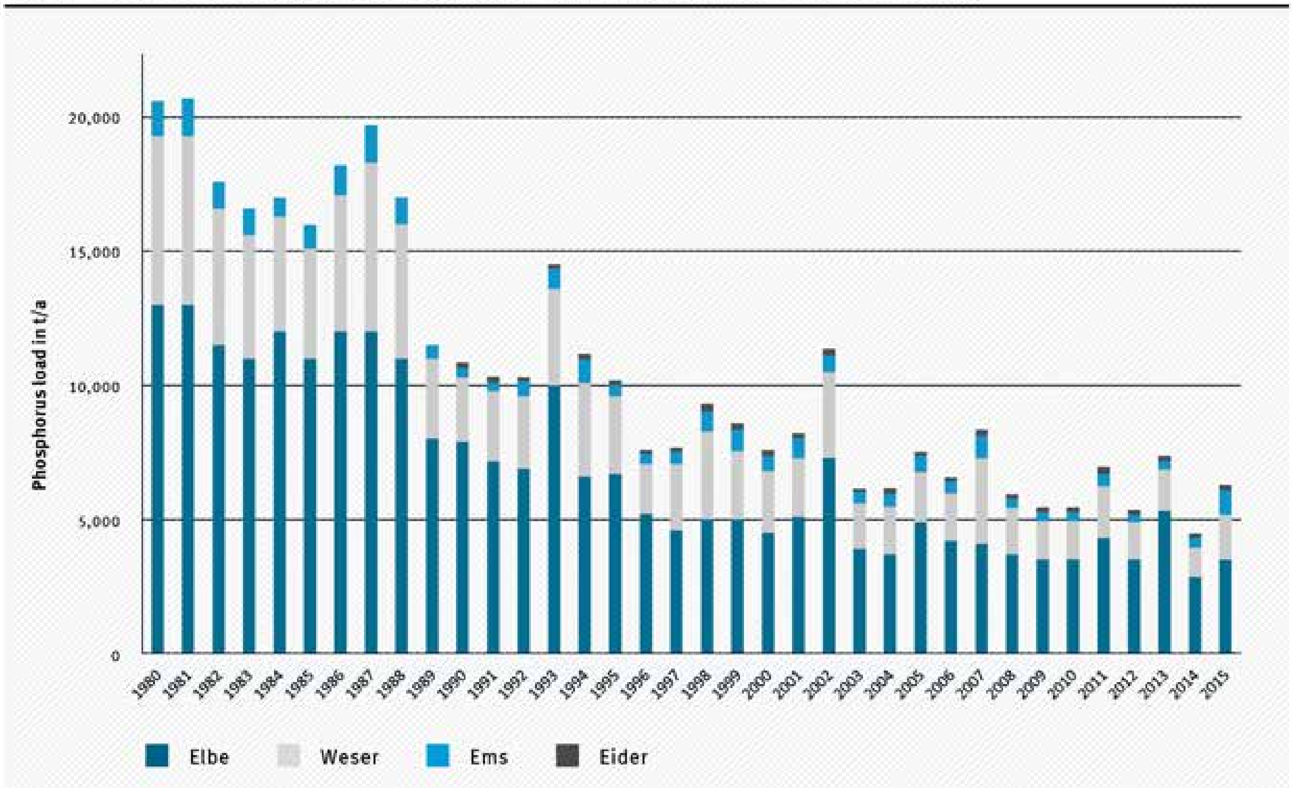
Time series of total nitrogen inputs via Germany's inflows into the North Sea, 1980–2015; for the river Eider, data is only available from 1990 onwards



Source: German Environment Agency using data supplied by the Laender for reporting under OSPAR, as of 2016

Figure 47

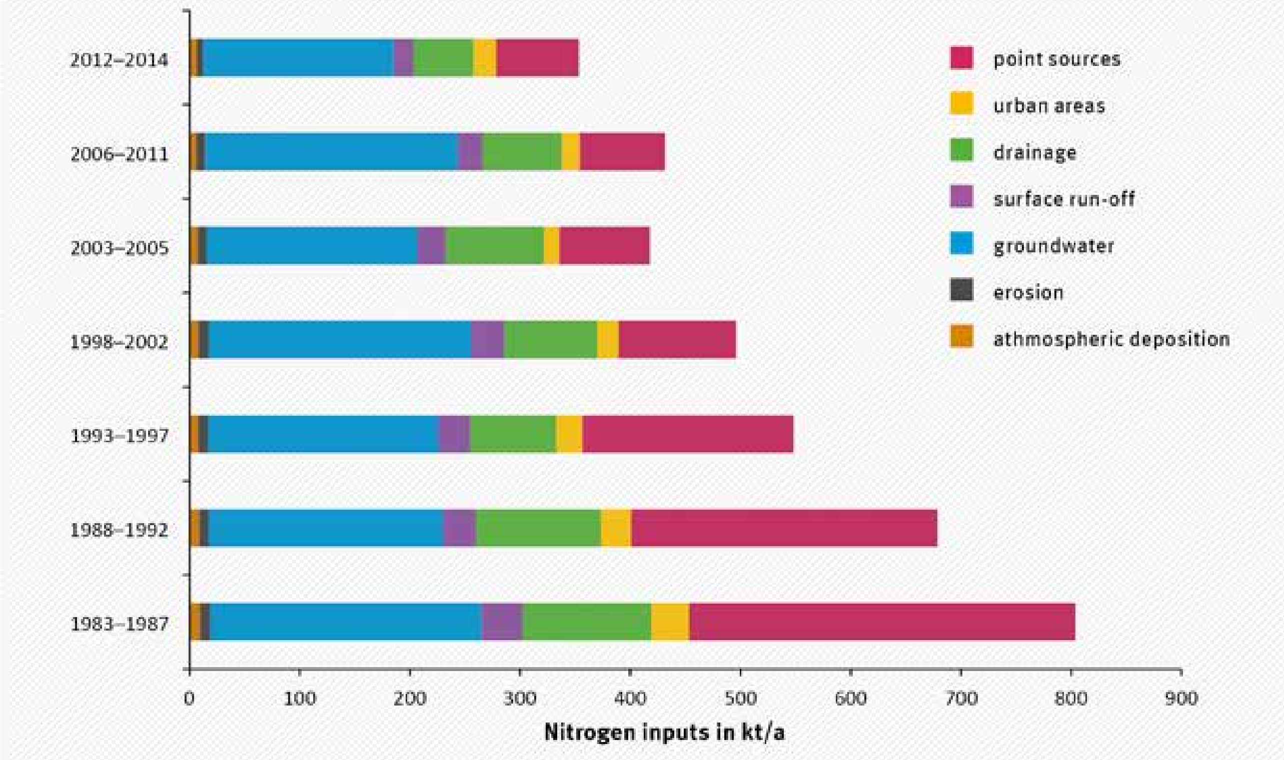
Time series of total phosphorus inputs via Germany's inflows into the North Sea, 1980–2015; for the river Eider, data is only available from 1990 onwards



Source: German Environment Agency using data supplied by the Laender for reporting under OSPAR, as of 2016

Figure 48

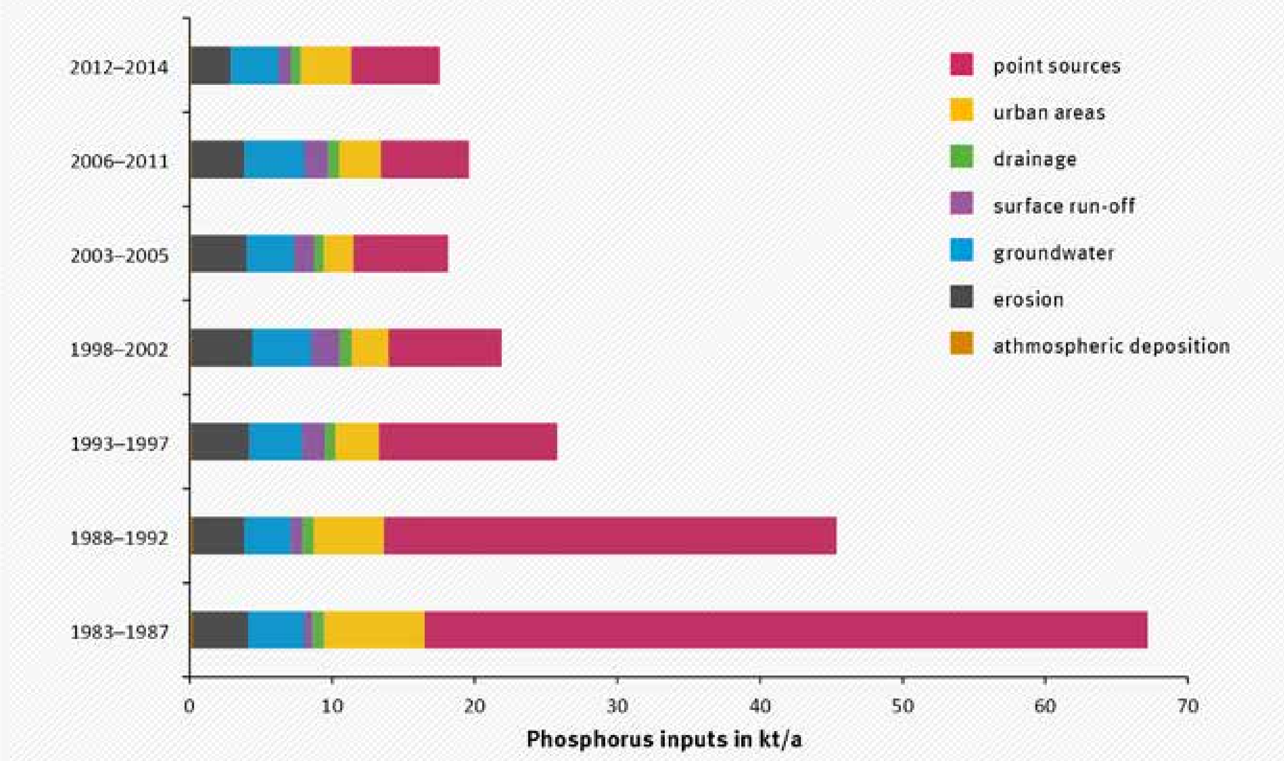
Nitrogen inputs into surface waters in the German catchment area of the North Sea



Source: German Environment Agency (MoRE), as of August 2016

Figure 49

Phosphorous inputs into surface waters in the German catchment area of the North Sea

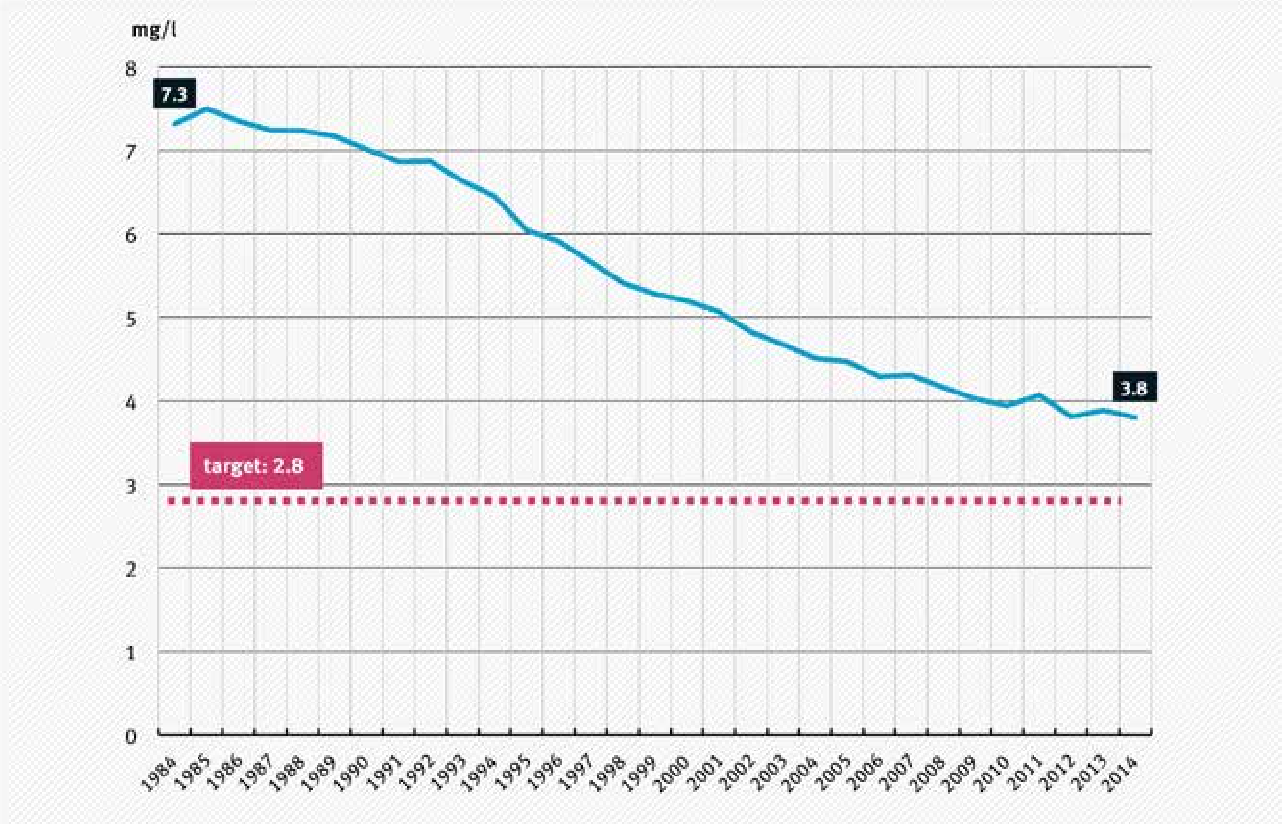


Source: German Environment Agency (MoRE), as of August 2016

Figure 50

Load weighted average of total nitrogen concentration of the rivers Elbe, Weser, Ems and Eider (5 years average)

For the river Eider, data is only available from 1990 onwards. Since there is no final decision on the assessment procedure and monitoring sites to be used the graph is preliminary.



Source: German Environment Agency based on data supplied by the Laender and/or river basin districts

areas (combined sewer overflows, rainwater discharges, and residents not connected to a municipal waste water treatment plant or sewer system) and the reduction in inputs via erosion.

The Ordinance on Surface Waters defines a management target of 2.8 mg/l total nitrogen at the transition from limnic to marine waters of the rivers discharging into the North Sea (§ 14 of OGewV). The load weighted average of the rivers Elbe, Weser, Ems and Eider exceed this target value (Figure 50). River Ems is the one exceeding this target most, attributable to the fact that the Ems catchment area includes regions of the highest cattle densities in Germany. A further reduction in nitrogen inputs is needed for coastal waters and marine waters to reach good status regarding eutrophication in line with the WFD, MSFD and the OSPAR strategy. In order to achieve good ecological status (WFD) and good environmental status (MSFD) for Germany's coastal and marine North Sea regions, it is also necessary to reduce remote inputs from other North Sea littoral states, which enter the German Bight in the southern North Sea due to the prevailing currents from the United Kingdom along the Belgian and Dutch coastlines.

Assessment of the eutrophication status

Under the Water Framework Directive, the assessment of the ecological status only applies up to one nautical mile (chapter 7.1.1). It is not an assessment of eutrophication in the true sense of the word; however, the results reflect the principal pressures on coastal waters, i.e. the excessive nutrient concentrations. This is the reason why they are presented below (Table 29, Figure 51).

Table 29

Classification of the ecological status/potential of water bodies of the transitional and coastal waters of the North Sea

Quality element	No. of water bodies					
	Bad	Poor	Moderate	Good	High	Not assessed
Phytoplankton	2	10	10	2	0	5
Makrophytes	0	6	7	7	0	9
Benthic invertebrates	0	2	18	5	3	1
Ecological status	2	12	15	0	0	0

Source: German Environment Agency after LAWA 2016b

All coastal and transitional waters of the North Sea fall short of good ecological status. For the German North Sea coast, 16 out of 28 water bodies of the coastal and transitional waters were assessed as "moderate", 10 as "poor" and 2 as "bad" (LAWA 2016b). In many water bodies, the biological quality elements phytoplankton, macrophytes and macrozoobenthos failed to achieve good status because they respond sensitively to nutrients.

The Wadden Sea is classed as a coastal water under the Water Framework Directive. In the Wadden Sea, eutrophication has led to algal bloom (foam algae Phaeocystis and green macroalgae), a reduction in the sea grass beds, and oxygen deficiency in the sediments. There are regional differences in the level of eutrophication, with the southern Wadden Sea generally being more severely affected by eutrophication.

Blooms of the slimeball or "foam algae" Phaeocystis globosa are particularly noticeable in the Wadden Sea. When these algal cells die off, the waves beat the layer of gelatine into foam, which is then blown ashore in large quantities by the wind.

Elevated cell densities of potentially toxic Dinophysis species repeatedly occur in the Wadden Sea of Lower Saxony. They produce a toxin which can cause diarrhoea and vomiting in humans (DSP, Diarrhetic Shellfish Poisoning). It is absorbed by eating mussels, which can accumulate this toxin through filtration after ingesting Dinophysis. If the DSP limits in mollusc flesh are exceeded, common mussels are prohibited from sale in Germany. Macroscopically visible carpets of green algae occurred for the first time on a large scale in the Wadden Sea around twenty years ago, and are an indicator of advancing eutrophication (Figure 52). They impair both the benthic fauna of the Wadden Sea and sea grass meadows in the tidal area. The benthic organisms, overlaid primarily with thread-like green algae, die as a result of oxygen deficiency or possible sulphide poisoning due to oxygen deficiency. The occurrence of green algae carpets has conspicuously changed the Wadden mudflats in summer. Since 2001, these green algae carpets in the Wadden Sea of Lower Saxony have tended to become less extensive, but with major fluctuations. The spread of green algae carpets in the Wadden Sea of Schleswig-Holstein has likewise decreased substantially.

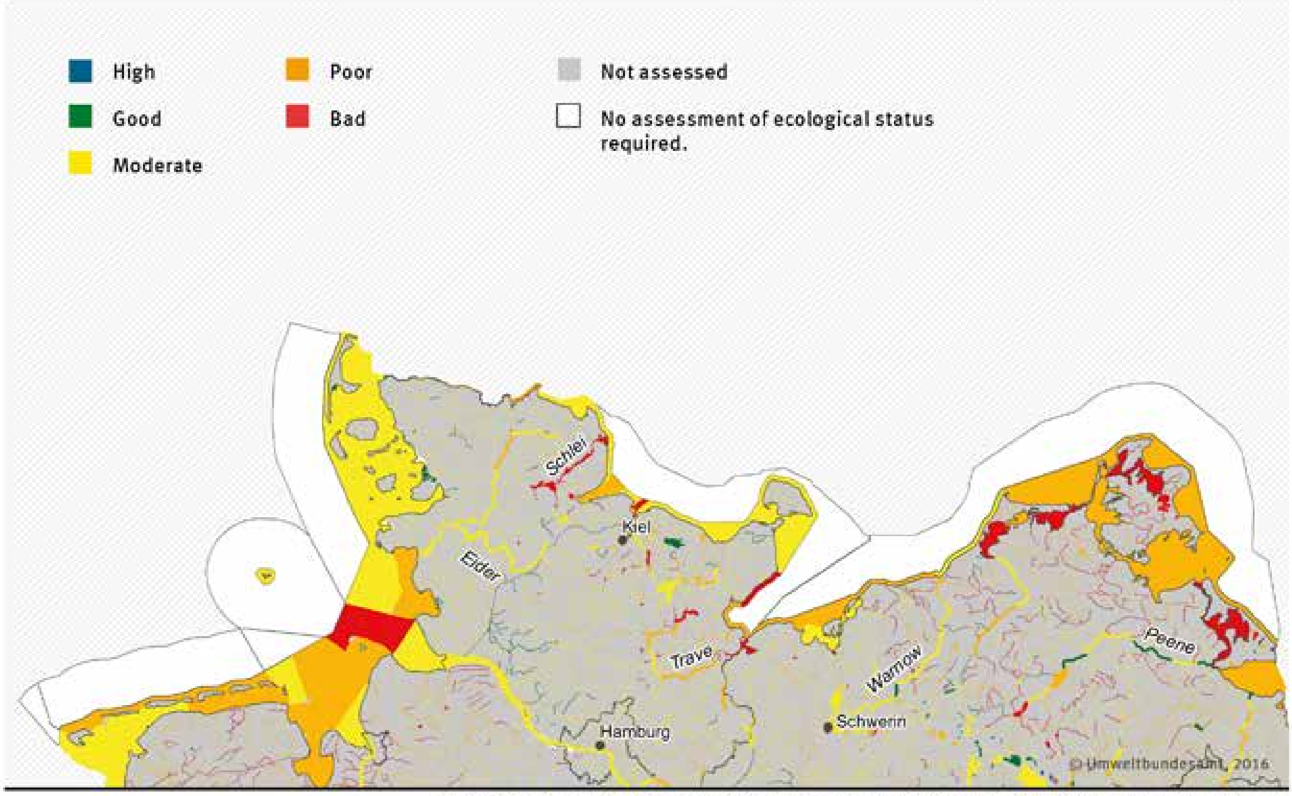
Small highland river close to the source
Source: Stephan Naumann

Sea grass beds in the tidal zone of the coast of Lower Saxony decreased until 2002 but recovered in subsequent years. From 2008 to 2013, the sea grass beds doubled in size from 19 km² to 38 km². However, the growth density in covered areas was significantly lower in summer 2013 than in 2008, and as a result, the assessment was less favourable overall (NLKWN and NLP-V 2016). Furthermore, sea grass meadows did not recover in all areas. For example, meadows of the large sea grass Zostera marina in the river Ems estuary on Hund-Paapsand mudflats have been virtually extinguished. The reasons are complex and include eutrophication, the sea grass wasting disease caused by the slime mold Layrinthula, and the reproduction strategy of sea grass, which is based solely on the annual production of seeds (Jager and Kolbe 2013). Findings of a research project indicate that the population area suitable for sea grass has decreased sharply due to the lowering of the Wadden Sea floor, caused by the exploitation of gas reserves by the Netherlands (Jager and Kolbe 2013). In the Wadden Sea area of Schleswig-Holstein, each year in August or September, records are kept of the tidal flats covered with more than 20 % sea grass meadows. In the period 1994 to 2015, this area increased from 26 to 150 km² (Figure 53).

The assessment under OSPAR includes coastal waters as defined by the WFD, together with marine regions up to 12 nautical miles and the Exclusive Economic Zone (EEZ). The first harmonised OSPAR eutrophication assessment (see chapter 7.1.2) in 2003 classified the inner

Figure 51

Ecological status/potential of water bodies of the transitional and coastal waters of the North and Baltic Seas



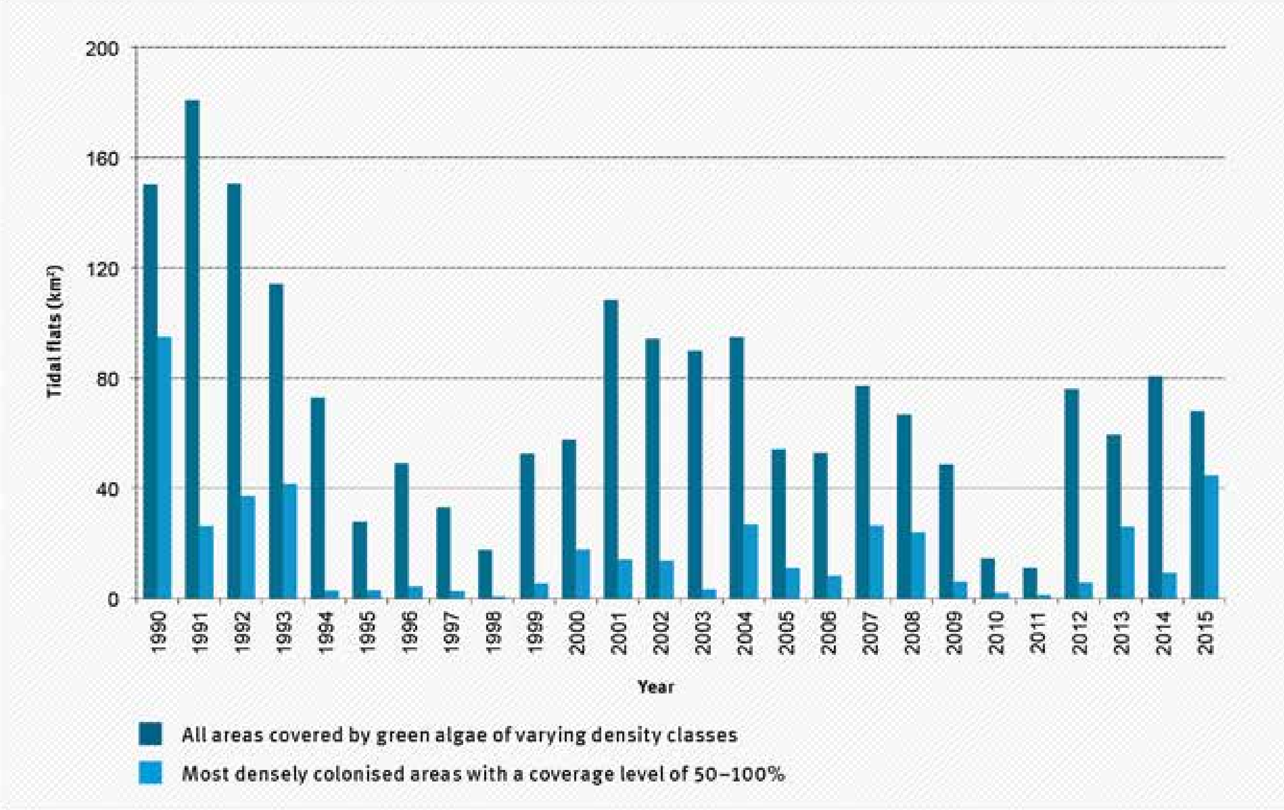
Source: Geobasis data: GeoBasis-DE/BKG 2015, professional data: LAWA 2016b, edited by: German Environment Agency, German Working Group on water issues of the Laender and the Federal Government (LAWA)

Green algae on tidal flats
Source: Dr. Wera Leujak

Foam algae on a North Sea beach
Source: Ulrich Claussen

Figure 52

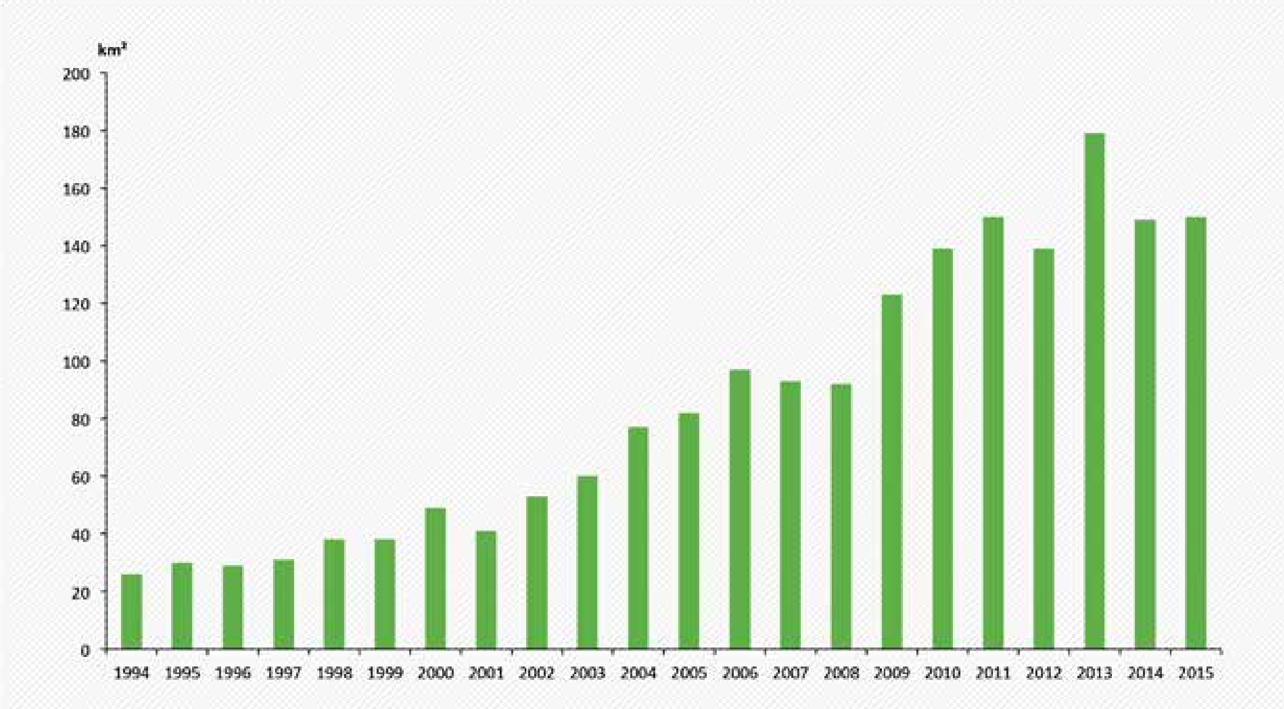
Tidal flats (km²) covered with green algae; the figures are based on aerial surveillance of the coast of Lower Saxony in the summers 1990 to 2015



Source: German Environment Agency based on data supplied by the State Agency for Water Management, Coastal Defence and Nature Conservation of Lower Saxony

Figure 53

Tidal flats covered with sea grass meadows (coverage > 20 %) following aerial surveillance of the Wadden Sea of Schleswig-Holstein in August or September between 1994 and 2015

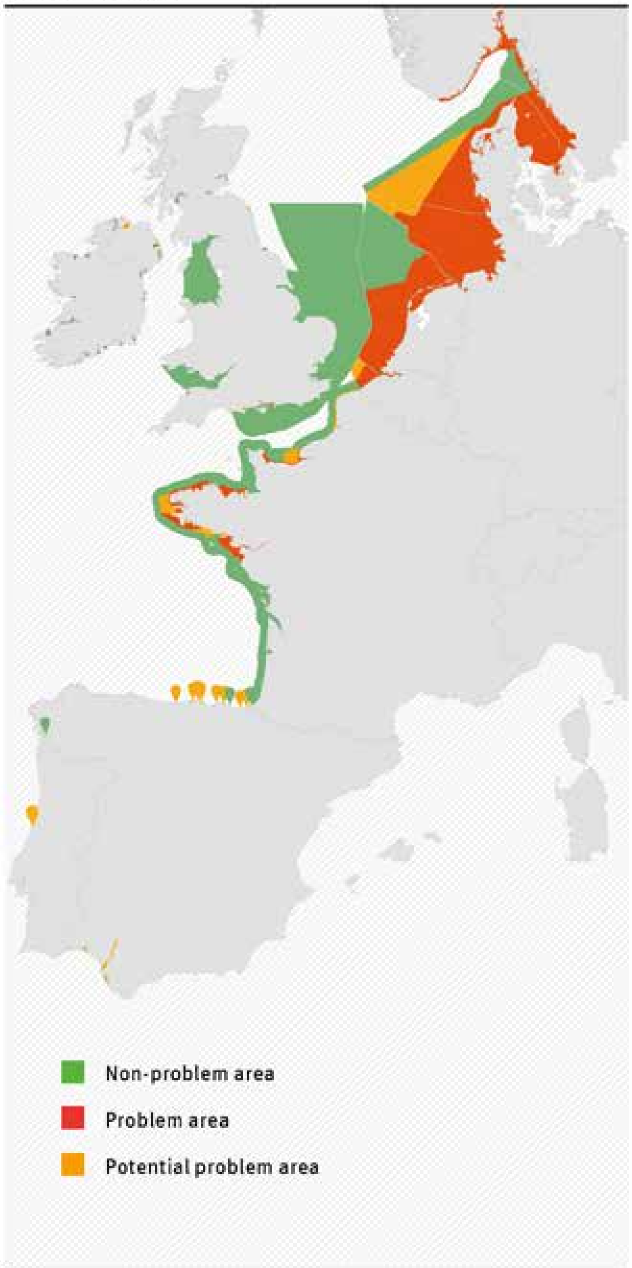


Source: German Environment Agency based on data supplied by the State Agency for Coastal Management, National Park and Protection of the Marine Environment of Schleswig-Holstein

German Bight, including the Wadden Sea, as problem area. The data was insufficient to allow an assessment of the offshore area, but it was, as a precaution, classified as potential problem area. Eutrophication effects in the German North Sea include an elevated phytoplankton biomass, regular summer oxygen deficiency in the estuaries and frequently in the bottom waters of the German Bight, restricted secchi depth, restricted spread of macrophytes, and changes to the populations of benthic organisms (zoobenthos).

Figure 54

OSPAR eutrophication status of the North-East Atlantic in 2007 (assessment period 2001–2005)



Source: OSPAR 2008

The assessment of the entire North Sea and the North-East Atlantic indicates that especially the southern North Sea is affected by eutrophication, together with some large areas along the Norwegian and Swedish coasts and a number of British estuaries. The second application of the common assessment procedure for eutrophication problem areas, based on data from 2001–2005, showed no significant improvement in the eutrophication status of the North Sea, including Germany's North Sea waters (Figures 54 and 55).

The provisional results of the third OSPAR eutrophication assessment for German North Sea waters, based on data from 2006–2014, reveal that the coastal waters must continue to be designated problem areas, but that the eutrophication status has improved in some areas of the open German Bight, and that the Entenschnabel / "Duck's Bill" (labelled OFFO in Figure 55) has now achieved the status of a non-problem area. The reduction in nutrient inputs is also gradually reaping benefits for other North Sea littoral states. Nutrient and phytoplankton concentrations are falling, and algal blooms are occurring less frequently. Nevertheless, further reduction efforts, in some case on a major scale, are still needed before the coastal waters are no longer eutrophicated and meet the targets of both WFD and MSFD.

In the context of the implementation of the Marine Strategy Framework Directive, which calls for a regionally harmonised assessment of the eutrophication status of the North Sea, OSPAR is currently developing regional indicators for concentrations of nutrients, chlorophyll-a and oxygen, and the number of Phaeocystis cells. Since 1990, concentrations of chlorophyll-a in the open southern North Sea have indicated a significant downward trend, but coastal waters have yet to exhibit an equivalent trend (Figure 56).

OSPAR Contracting Parties had undertaken to reduce emissions of nitrogen and phosphorus by 50 % by 2010 compared with 1985 levels. While nearly all littoral states met the target for phosphorus, the majority of signatories (with the exception of Denmark, the Netherlands and Germany) need to reduce their nitrogen inputs further. Models show that the aspired reduction target of 50 % of nutrient emissions via rivers is insufficient to successfully tackle eutrophication, and that in some areas, nitrogen reductions of up to 90 % are needed. Because of the marine ecosystem's time-delayed response, it may take 10 to 30 years for the eutrophication status of an affected region to significantly improve.

OSPAR has recognized that the blanket targets set in the past were a positive and important joint first step towards tackling eutrophication. Individual targets are now being set for the individual problem areas already identified, and will incorporate into the balances nutrient emissions from neighbouring marine regions which may not themselves indicate any symptoms of eutrophication, as well as atmospheric nutrient emissions. This work was due for completion back 2012, but was hampered by political resistance.

Long-term studies of nutrients and plankton in the German Bight indicate that phosphate-induced eutrophication of the German Bight began as early as the 1960s, partly as a result of the large-scale use of detergents containing phosphates. Annual average winter phosphate concentrations near Helgoland increased sharply until the mid-1970s. They remained at this level for around a decade and then fell again as a result of measures to reduce phosphate, such as the introduction of phosphate-free detergents and the installation of phosphate elimination systems in industrial and public wastewater treatment plants. Total nitrogen concentrations have fallen since 2000, but remain more than double the benchmark (chapter 7.1.2). Partly due to gaps in the time series, total phosphorus concentrations do not exhibit a clear trend, and in 2015 were more than double the benchmark (Figure 57). For this reason, the situation regarding the ecological impacts of elevated nutrient levels (eutrophication) remains far from being satisfactory.

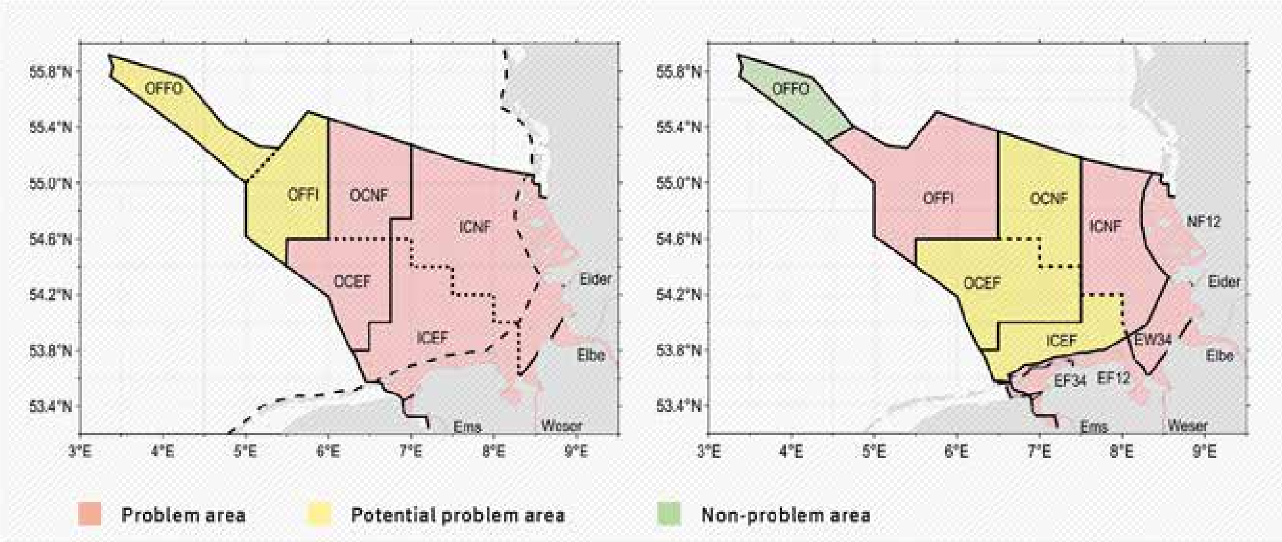
The ecological status of benthic fauna in transitional and coastal waters is predominantly "moderate", and in some cases "good" or "high" (see Table 29). Benthic fauna is impaired by oxygen deficiency. Summer oxygen deficiency, initiated by the decomposition of organic compounds, has been regularly observed in the estuaries of the rivers Elbe, Weser and Ems. Since the early 1980s, in summer, oxygen deficiency has also been repeatedly observed in near-ground water strata of the German Bight. The occurrence of this widespread phenomenon followed unusual phytoplankton blooms in spring. With the microbial decomposition of descended biomass, under certain hydrographical and meteorological conditions (stratified water bodies), oxygen depletion can occur in bottom waters. Depending on the geographical extent and duration of the oxygen deficiency, benthic organisms may be impaired to a greater or lesser extent. Adapted, robust and opportunistic species withstand this situation better than more sensitive species such as starfish and sea urchins. Subject to their living conditions, some fish may migrate from the area and therefore have significantly higher rates of survival than sessile organisms.

Small highland river close to the source
Source: Stephan Naumann

Figure 55

Result of the second and third application of the OSPAR eutrophication assessment method "Common Procedure" (COMP) on German coastal waters and the German Bight

left: Eutrophication status in the period 2001–2005; right: Eutrophication status in the period 2006–2014

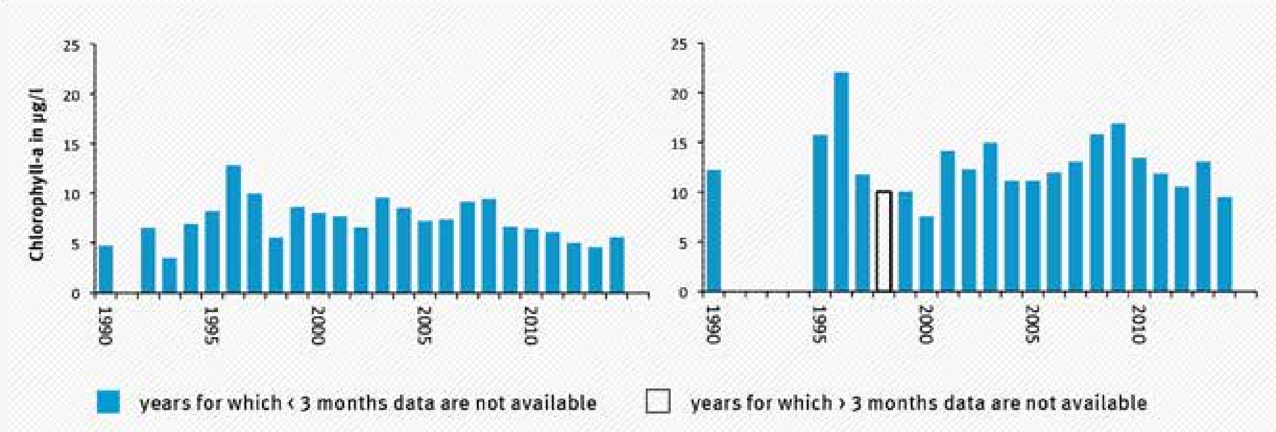


Source: Brockmann et al. 2016

Figure 56

Trend for chlorophyll-a concentrations in µg/l during the growing season (March–September) in the southern North Sea, 1990–2015

left: Open sea (salt content > 30); right: Coastal waters (salt content 18–30)



Source: OSPAR 2017a

7.2.1.2 Eutrophication of the Baltic Sea

Nutrient inputs

Substance concentrations and substance loads for the catchment areas of the Baltic Sea are likewise balanced according to the model approach (MoRE). The calculated loads of phosphorus and nitrogen compounds from German inflows into the Baltic Sea have been declining for many years. However, there are some very sharp fluctuations from year to year, as a result of variations in outflow rates (Figures 58 and 59). In 2014, around 2,800 t of nitrogen and 110 t of phosphorus were emitted into the Baltic Sea via the rivers Trave, Peene and Warnow. These figures disregard both nitrogen inputs from smaller inflows and inputs from Germany into the Baltic Sea via the river Oder (Figure 60). If these are additionally taken into account, in 2014 some 9,600 tonnes of nitrogen and around 360 tonnes of phosphorus were discharged into the Baltic Sea.

For balancing the inputs from land into the Baltic Sea, anthropogenic substance inputs from point and diffuse sources throughout the entire Baltic Sea catchment area are quantified using the MoRE model. The model results disregard retention in the water bodies, in other words, the balanced inputs are higher than the loads. Between 1983–1987 and 2012–2014, the modelled inputs into the surface waters of the German Baltic Sea catchment area (Warnow/Peene, Schlei/Trave and Oder river basin districts) were reduced from 63,000 t/a to 22,200 t/a of nitrogen, and from 3,600 t/a to approximately 800 t/a of phosphorus. This means that for the period 2012–2014, nitrogen and phosphorus inputs had been reduced by 65 % (nitrogen) and 78 % (phosphorus) respectively compared with the period 1983–1987 (Figures 61 and 62).

Nitrogen inputs were reduced due to a sharp fall in inputs from point sources (approximately 87 %). The proportion of nitrogen inputs from point sources among total nitrogen inputs decreased from 25 % to 9 % in the period under review, while the contribution from diffuse sources increased, with inputs via agriculture accounting for 86 %. Drainage and groundwater are the dominant diffuse emission pathways, amounting to 46 % and 26 % respectively. Nitrogen inputs from diffuse sources decreased by around 57 %. The 78 % approximate reduction in phosphorous inputs is likewise primarily attributable to the reduction in emissions from point sources (94 %). Given the sharp reduction in phosphorus emissions from point sources, these no longer represented the dominant emission pathway for the period 2012–2014, accounting for 20 % as against 72 % in 1985. In the period 2012–2014, phosphorous emissions from diffuse sources accounted for 80 % of total phosphorous emissions, around 64 % of which was attributable to agriculture. Overall, phosphorus emissions from diffuse sources decreased by 37 % during the period under review. Among diffuse emission pathways, inputs from urban areas predominate (21 %).

Figure 57

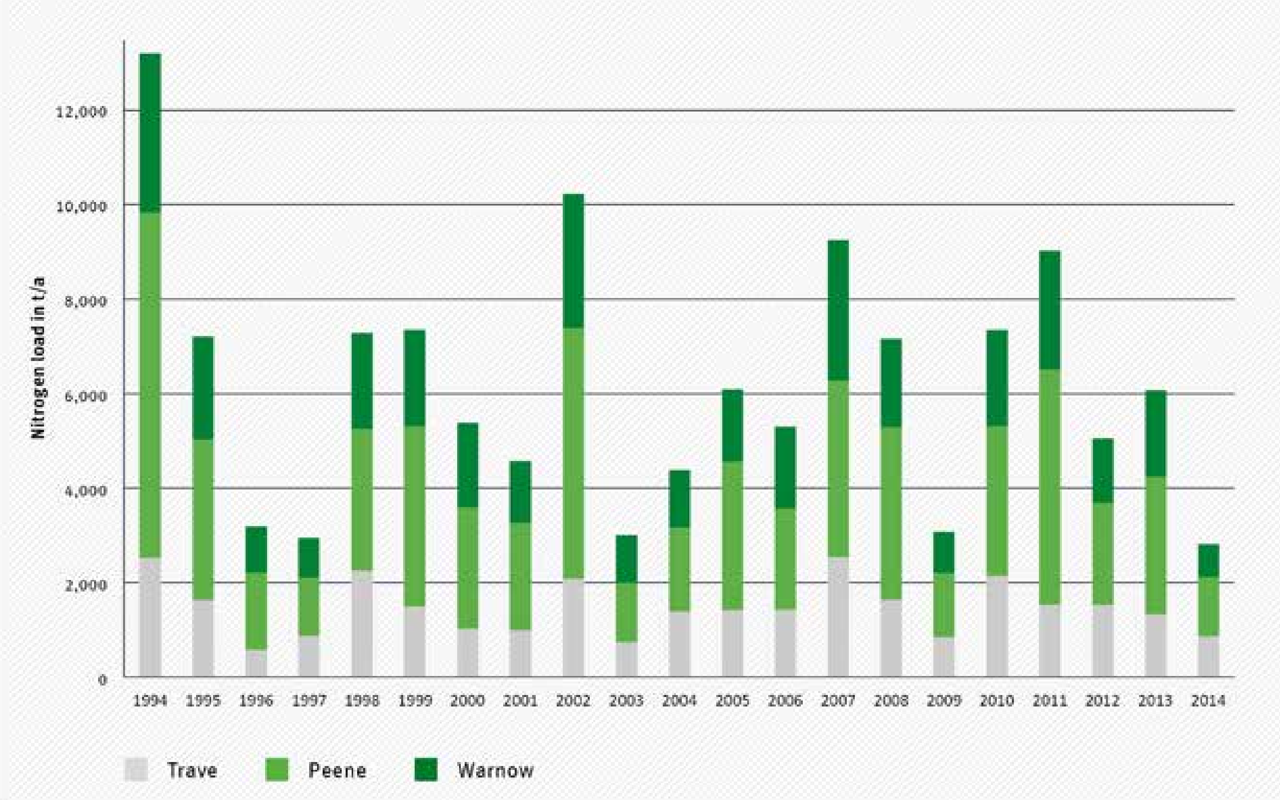
Time series of measured annual nutrient concentrations in the coastal waters of the German Bight (salt content 30) with standard error bars for total nitrogen (TN) and total phosphorus (TP) and the respective benchmarks

Values for TN for the period 1997–2005 are calculated from correlations with dissolved inorganic nitrogen, and therefore, no error bar can be displayed; TP was not measured between 1997 and 2005, and since there is no correlation with dissolved inorganic phosphorus, the TP concentrations could not be calculated.

Source: German Environment Agency based on data supplied by the Federal Maritime and Hydrographic Agency

Figure 58

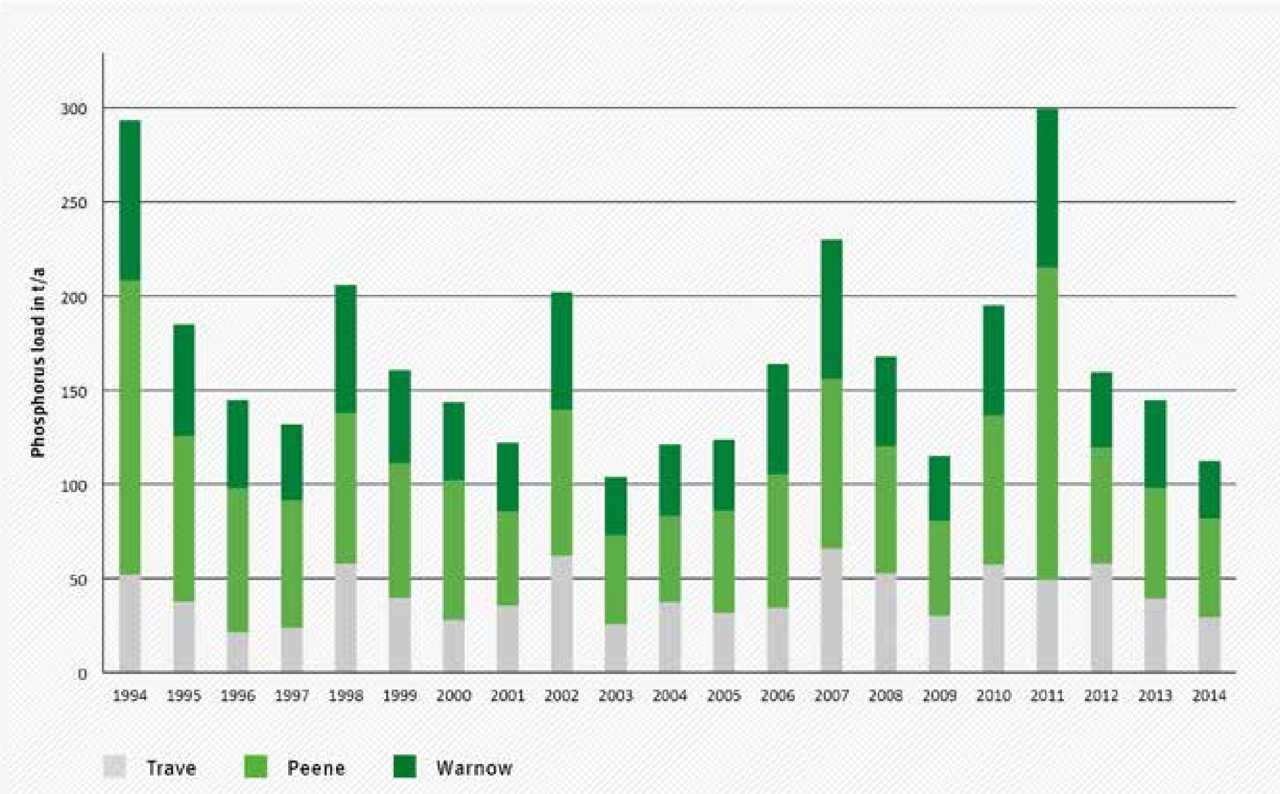
Time series of total nitrogen inputs via German rivers into the Baltic Sea, 1994–2014



Source: German Environment Agency based on data supplied by the Laender for reporting under HELCOM, as of 2016

Figure 59

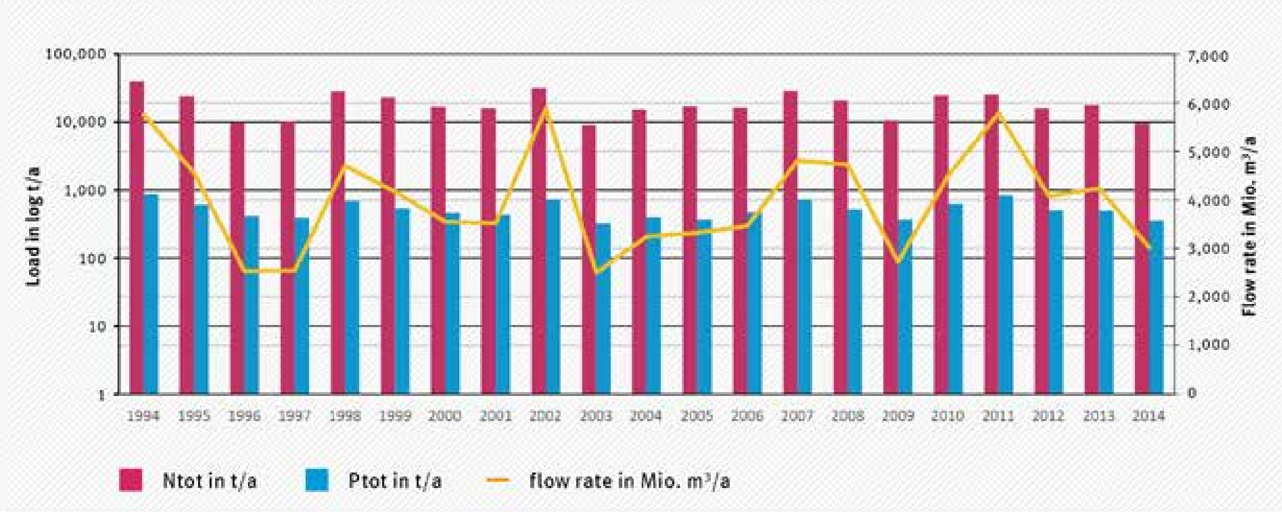
Time series of total phosphorus inputs via German rivers into the Baltic Sea, 1994–2014



Source: German Environment Agency based on data supplied by the Laender for reporting under HELCOM, as of 2016

Figure 60

Time series of total nitrogen and total phosphorus inputs via German rivers and unmonitored areas into the Baltic Sea, 1994–2014;
for a better visualisation of the low phosphorus loads compared with the higher nitrogen loads, a logarithmic scale has been used



Source: German Environment Agency based on data supplied by the Laender for reporting under HELCOM, as of 2016

Source: Stephan Naumann

The Ordinance on Surface Waters defines a management target of 2.6 mg/l total nitrogen at the transition from limnic to marine waters of the rivers discharging into the Baltic Sea (§ 14 of OGewV). The load weighted average of the rivers Schlei/Trave, Warnow and Peene exceed this target value (Figure 63). A further reduction in nitrogen inputs is needed so that coastal and marine waters may reach good status with respect to eutrophication in line with the WFD, MSFD and Baltic Sea Action Plan.

Nutrient reduction targets under the HELCOM Baltic Sea Action Plan

At a HELCOM Ministerial Meeting in Crakow in November 2007, the Contracting Parties to the Helsinki Convention adopted the Baltic Sea Action Plan, containing ambitious nutrient reduction targets. Germany agreed to reduce nitrogen inputs into the Baltic Sea by 5,620 t by 2016, and phosphorus inputs by 240 t.

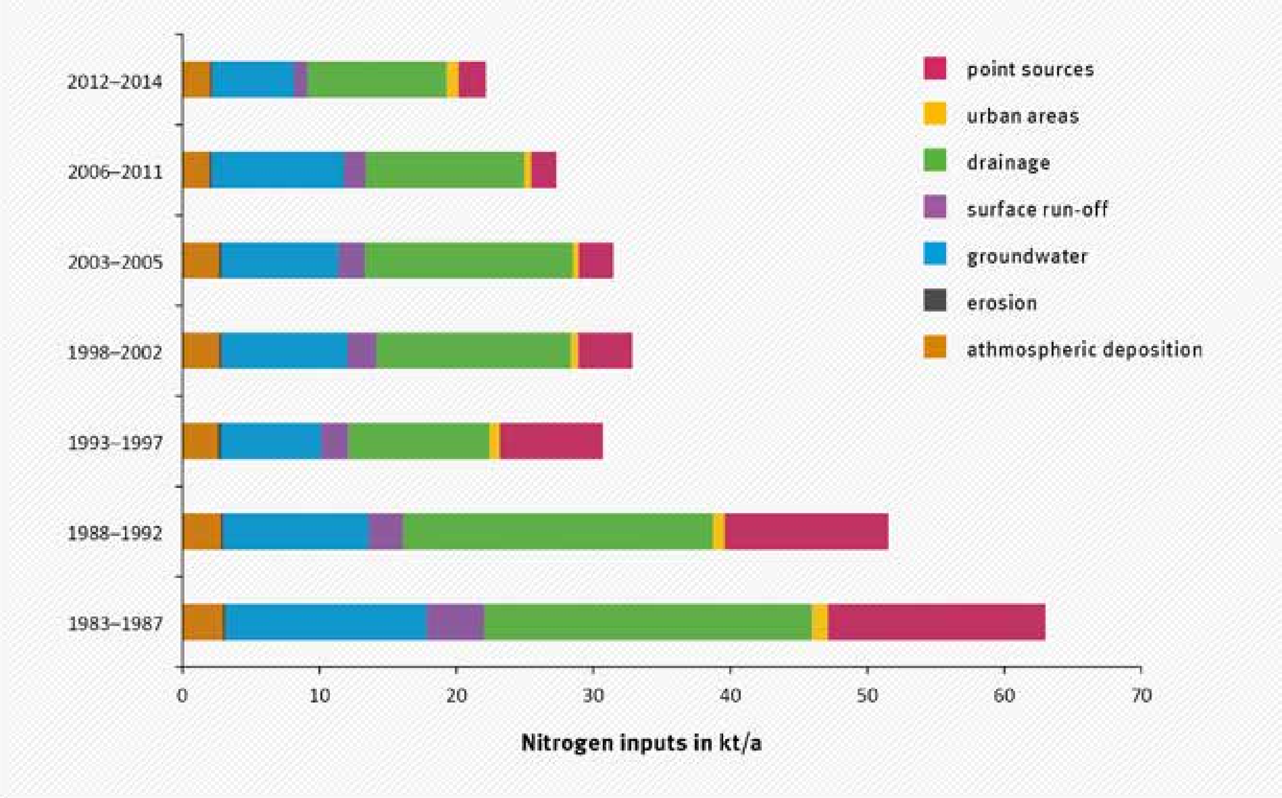
In May 2010, the HELCOM Ministerial Meeting in Moscow voted for a scientific review of the above reduction targets, which was carried out by the Swedish Baltic Nest Institute, based on an improved database and scientifically derived targets. In Copenhagen, the HELCOM Ministerial Meeting adopted on 3 October 2013 new targets, which considered atmospheric nitrogen loads for the first time and drafted specific reduction requirements for non-signatories and shipping. In the ministerial declaration, Germany committed to reduce nitrogen loads by 7,670 t by 2016, and phosphorus loads by 170 t, compared with the reference period 1997–2003. A first data collection in 2014 showed that nitrogen loads had already decreased by 5,000 t, putting Germany on track for meeting its HELCOM reduction targets by 2021 (Figure 64). The reduction of atmospheric nitrogen emissions under the Göteborg Protocol made a key contribution to these reductions. By contrast, phosphorus loads have risen slightly due to runoff-related reasons, so that by 2014, the reduction target had risen to 208 t (Figure 65).

Assessment of the eutrophication status of the Baltic Sea

Because of its character as a semi-enclosed sea and minimal water exchange with the North Sea, the Baltic Sea is sensitive to eutrophication. According to the Water Framework Directive, the coastal waters of the Baltic Sea are predominantly in “poor” or “bad” status. 15 of the 45 water bodies were assessed as “moderate”, 15 as “poor” and 15 as “bad” (Table 30, Figure 51). Among those German Baltic Sea coastal waters assessed as “bad”, the majority are water zones with low exchange rates or long retention periods (Peenestrom, Kleiner Jasmunder and Barther Bodden, Untere Trave and Travemünde, Innere and Mittlere Schlei).

Figure 61

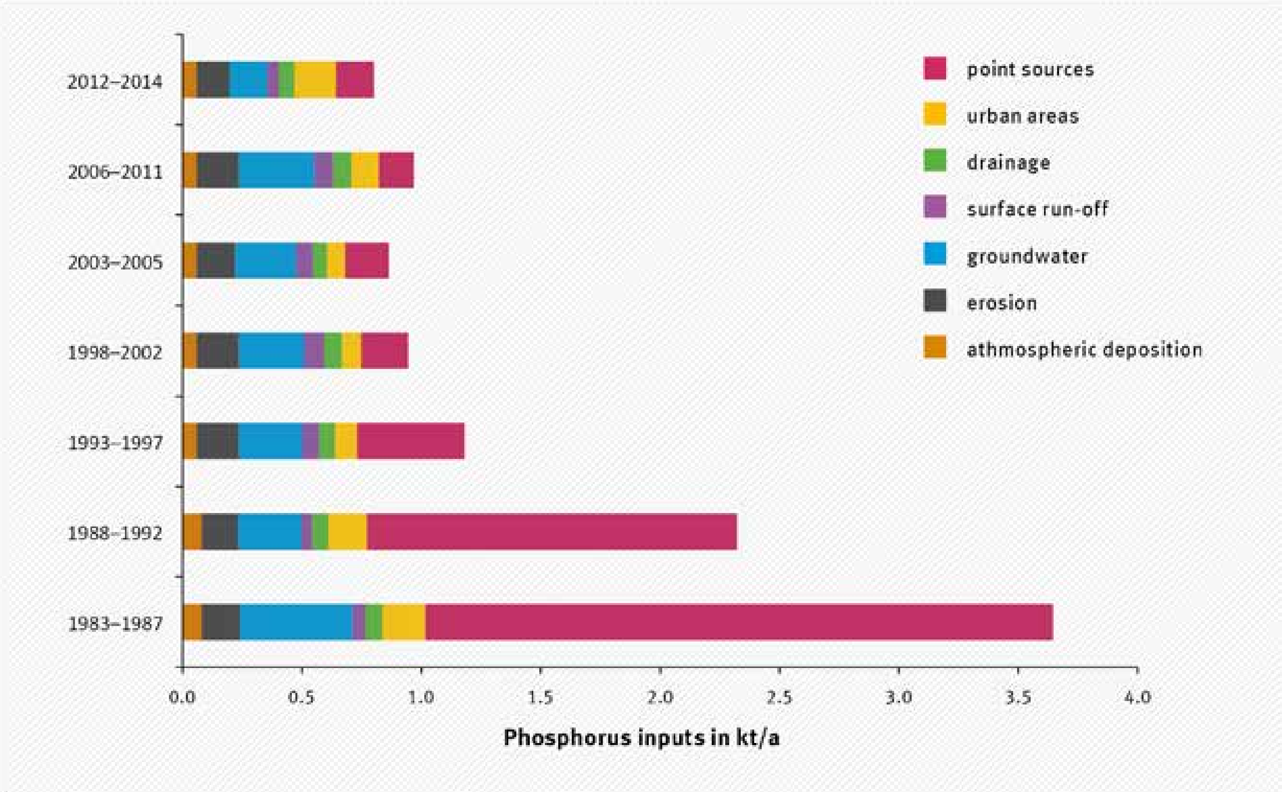
Nitrogen inputs into surface waters in the German catchment area of the Baltic Sea



Source: German Environment Agency (MoRE), as of August 2016

Figure 62

Phosphorus inputs into surface waters in the German catchment area of the Baltic Sea

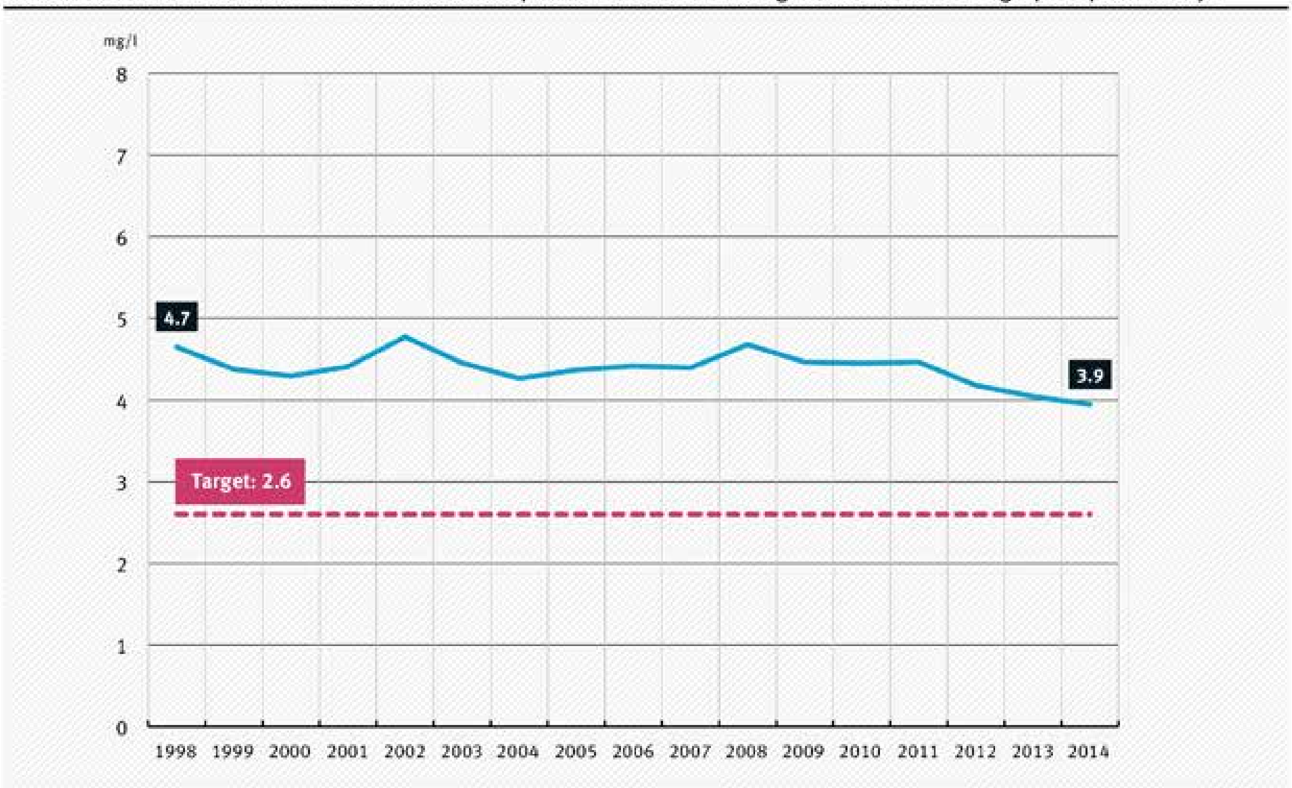


Source: German Environment Agency (MoRE), as of August 2016

Figure 63

Load weighted average of total nitrogen concentration of the rivers Schlei/Trave, Warnow and Peene (5 years average)

Since there is no final decision on the assessment procedure and monitoring sites to be used the graph is preliminary.



Source: German Environment Agency based on data supplied by the Laender and/or river basin districts

Algal bloom on a Baltic Sea beach
Source: Dr. Wera Leujak

The underwater vegetation responds very sensitively to high discharges of nutrients. The associated increased turbidity of the water column due to phytoplankton leads to a deterioration in the underwater light conditions and hence to a reduction in habitats suitable for colonisation. Large algae and flowering plants are displaced from the deeper sections to the shallow water zones of the coastal waters. Former spread depths for sea grass (10 m) and bladderwrack (20 m) are no longer reached today. Recent studies suggest that there is very little bladderwrack remaining along the coast of Mecklenburg-Western Pomerania. Sea grass meadows in the Prerow Bight are overgrown with thread-like algae that have become established due to over fertilisation and which blanket the sea grass.

Table 30

Classification of the ecological status/ potential of water bodies in coastal waters of the Baltic Sea

Quality element	No. of water bodies					
	Bad	Poor	Moderate	Good	High	Not assessed
Phytoplankton	10	11	16	5	2	0
Macrophytes	6	12	16	3	0	7
Benthic invertebrates	5	3	29	5	0	2
Ecological status	15	14	15	0	0	0

Source: German Environment Agency after LAWA 2016b

Severe blue-green algal bloom occurs periodically, and huge carpets of algae drift onto the beaches of Mecklenburg-West Pomerania and Schleswig-Holstein. The algal bloom reduces secchi depth, which may be less than 0.5 m in the estuaries of the rivers Oder and Warnow, for example.

The regional HELCOM assessments of data from 2003–2007 and 2007–2011 indicate that almost the entire Baltic Sea must be classed as eutrophicated (Figure 66). Only Bothnian Bay has some zones in good status. The German waters of the Baltic Sea (coastal waters under the WFD and open sea) are also affected by eutrophication. The next HELCOM eutrophication assessment is scheduled for spring 2017. Initial data analyses suggest that there has been no material improvement in the eutrophication status.

Because of the direct inflows from rivers, particularly the Oder, the coastal waters and inner bays are more polluted by nutrient inputs than the Baltic Sea outside the 1 nautical mile zone. Whereas phosphate levels are generally two to three times higher than on the outer coast, nitrate concentrations can exceed the levels of the offshore Baltic Sea by a multiple. This becomes particularly apparent in the rivers Innere Schlei and Unterwarnow, in the lagoon Kleines Haff and in the Pomeranian Bight. Nutrient concentrations in the inner Bodden waters have decreased substantially since the 1990s, whereas in coastal waters there has been no significant decrease. This is thought to be due to the remobilisation of large quantities of phosphate from the oxygen-deficient sediment. Schlungbaum et al. (2001) calculated the phosphorus input into the Darß-Zingst chain of Bodden waters via rivers and the aerial pathway at 99 t, and release from sediment at 360 to 480 t of phosphorus. Internal nutrient inputs are a massive problem for the entire Baltic Sea. It is estimated that in the past 50 years, 40 million tonnes of phosphorus were deposited in Baltic Sea sediment due to excessive anthropogenic nutrient loads. In the event of oxygen deficiency, these can then be released due to the prevailing redox conditions, cancelling out efforts to reduce nutrient levels to some extent (Gustafsson et al. 2012). The nutrient reduction figures in the Baltic Sea Action Plan already make allowance for this important source of nutrients, which means that, even with immediate implementation of the nutrient reduction requirements, a good eutrophication status will be achieved in 100 years at the earliest.

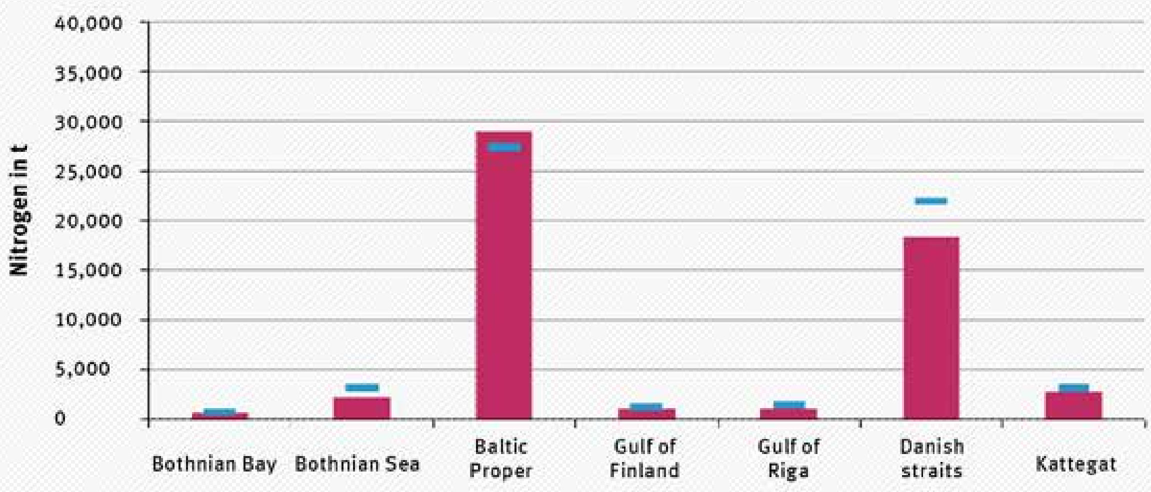
For the open Baltic Sea, longer data series indicate a rise in nitrate concentrations up until the late 1980s, followed by a continuous decrease. Phosphate concentrations follow this trend but have shown pronounced fluctuations in recent years.

Benthic organisms are heavily impaired by the lack of oxygen. It can take macrozoobenthos up to 4 years to recover from oxygen deficiency events. Oxygen deficiency is a naturally occurring phenomenon in the Baltic Sea. However, frequency, strength and spatial extent of oxygen-deficient and oxygen-free zones (dead zones) caused by excessive nutrient inputs have increased substantially as a result of human activity. In the coastal waters of Schleswig- Holstein and Mecklenburg-Western Pomerania, as off the Danish coast, oxygen deficits occur every

Figure 64

Average normalised waterborne and atmospheric nitrogen loads 2010–2012 compared with the admissible load (blue line) per basin

Because of the prevailing west winds, Germany emits nitrogen into all Baltic Sea basins via the atmosphere, and must therefore meet reduction requirements for all basins.



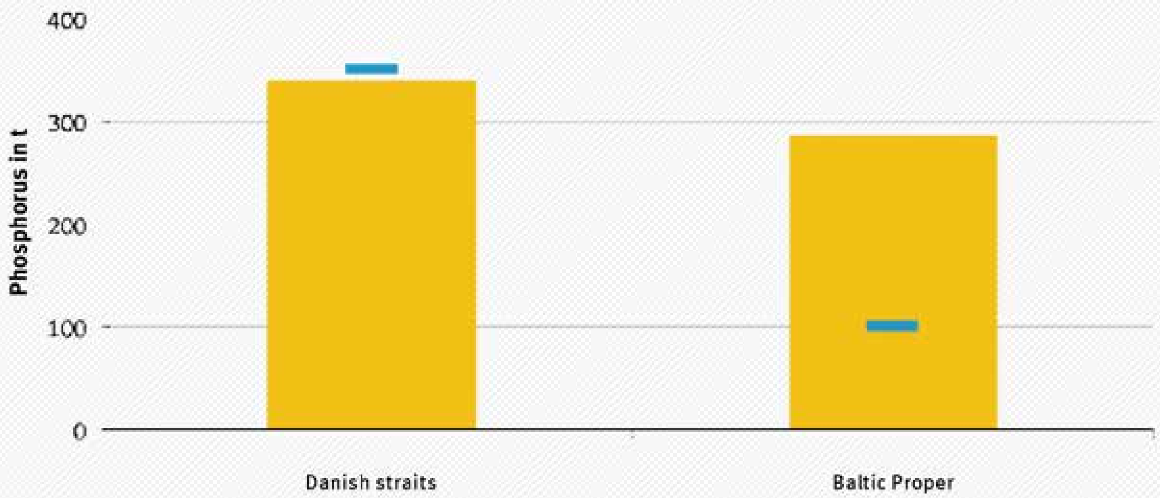
Source: HELCOM 2015

Source: Stephan Naumann

Figure 65

Average normalised waterborne and atmospheric phosphorus loads 2010–2012 compared with the admissible load (blue line) per basin according to the Baltic Sea Action Plan

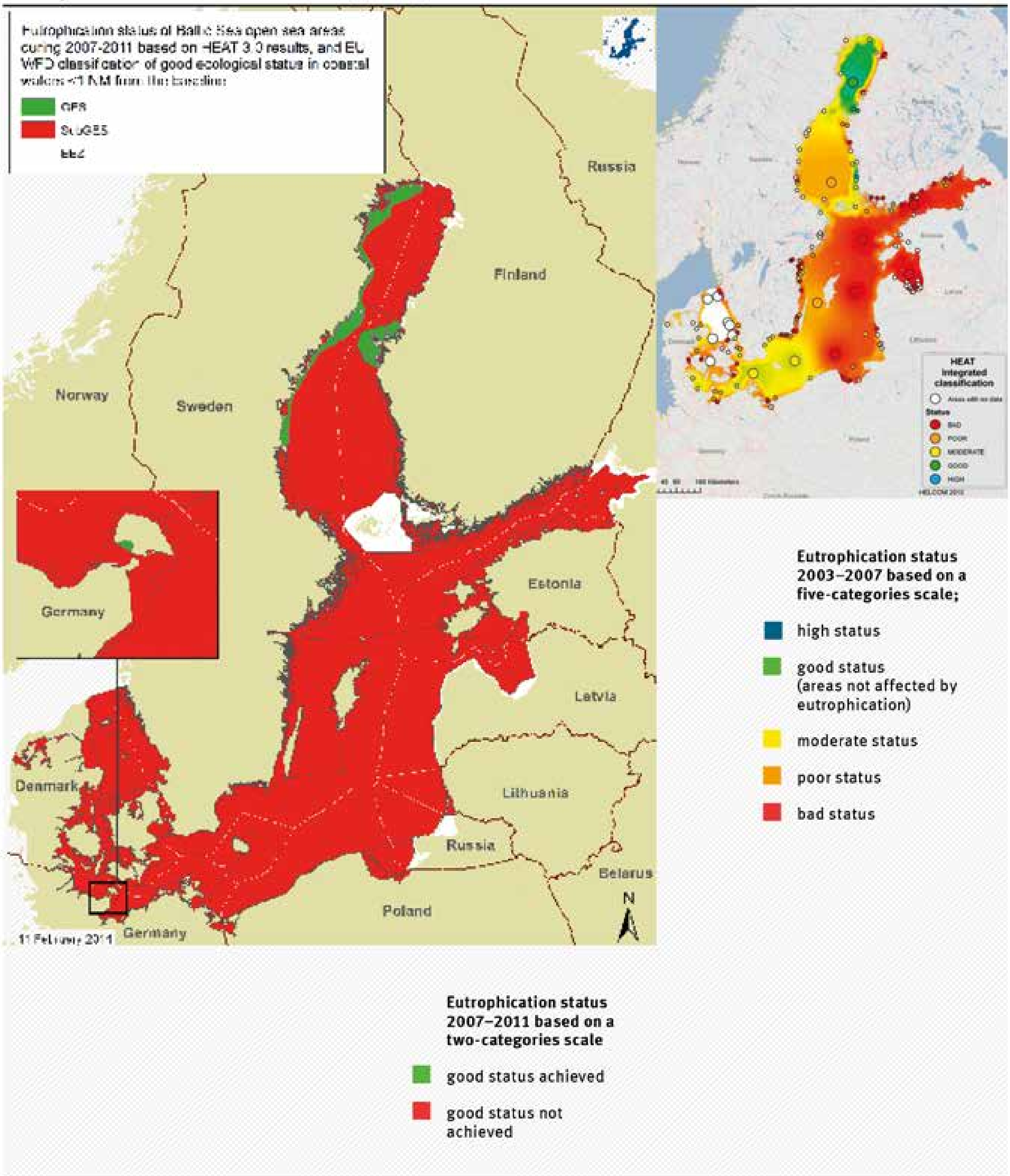
In the case of phosphorus, nutrient reduction targets were only defined for waterborne loads, which is why phosphorus inputs are only shown for those Baltic Sea basins into which German rivers discharge.



Source: HELCOM 2015

Figure 66

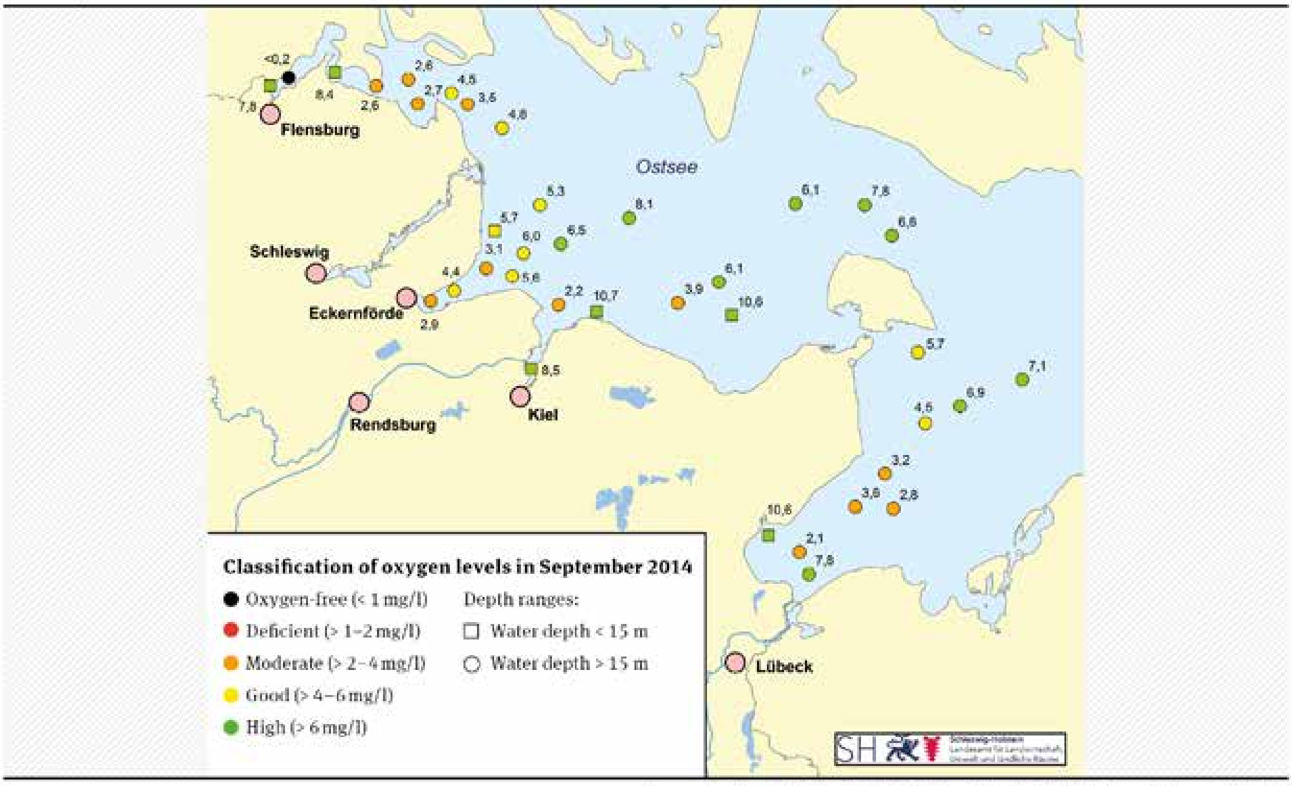
HELCOM classification of the eutrophication status of the Baltic Sea based on the HELCOM Eutrophication Assessment Tool (HEAT)



Source: HELCOM, 2010 and 2014

Figure 67

Measuring site-specific classified oxygen levels in deep waters of the western Baltic Sea in September 2015



Source: Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein

year during summer and autumn. A recent survey of Baltic Sea waters of Schleswig-Holstein indicates 63 % poor to bad oxygen concentration levels (Figure 67).

7.2.2 Pollutants

Similar to rivers and lakes, the chemical status according to the Water Framework Directive for transitional and coastal waters consistently is failing to achieve good status (refer to the brochure "The Water Framework Directive – The status of German waters 2015"). High concentrations of mercury in fish are one of the reasons (see also Table 31). Analysis results from Mecklenburg-Western Pomerania (Table 31) and the Environmental Specimen Bank (see chapter 7.2.2.2) also indicate exceedance of the environmental quality standard for fish (biota-EQS) with brominated diphenyl ether (BDE).

The OSPAR assessment criteria (Table 28) for lead and cadmium are exceeded in common mussels in both the North and Baltic Seas, but are now met in the case of tributyl tin.

7.2.2.1 Heavy metals

The Water Framework Directive classifies the heavy metals mercury, lead and cadmium as priority hazardous substances. They serve as indicators for assessing the environmental status of the North and Baltic Seas.

Heavy metal concentrations in water

The Baltic Sea and the North Sea did not exceed the environmental quality standards for lead, mercury and cadmium in the water phase in the period 2012–2015 (see chapter 4.2.3). For monitoring sites located outside of the 12 nautical mile zone, the levels were essentially lower than inside the zone. This shows that a significant proportion of inputs originates from rivers, and become increasingly diluted with seawater farther offshore.

Heavy metals in marine organisms

Analyses of heavy metals in the North Sea were conducted using common mussel flesh and eel-pout specimens stored in the Environmental Specimen Bank, collected from Sylt-Römö-Watt, Jade Estuary and Meldorf Bight between 1988 and 2014. Over this period, the levels of lead and cadmium in common mussels decreased continuously. Specimens from the early 1990s indicate higher concentrations of lead and cadmium in the Jade

Estuary than in Sylt-Römo-Watt. Over the past twenty years, these differences have decreased. The most striking decrease was for lead: Between 1992 and 2014, the lead content in common mussels from the Jade Estuary decreased by almost 70 %. In 2014, cadmium and lead levels in common mussels from the Jade Estuary were above background concentration levels, while those from Sylt-Römo-Watt were mainly below them in the case of lead (Figures 68 and 69).

Table 31

Results of pollution measurements in biota in the period between 2013 and 2015, in the coastal waters of Mecklenburg-Western Pomerania

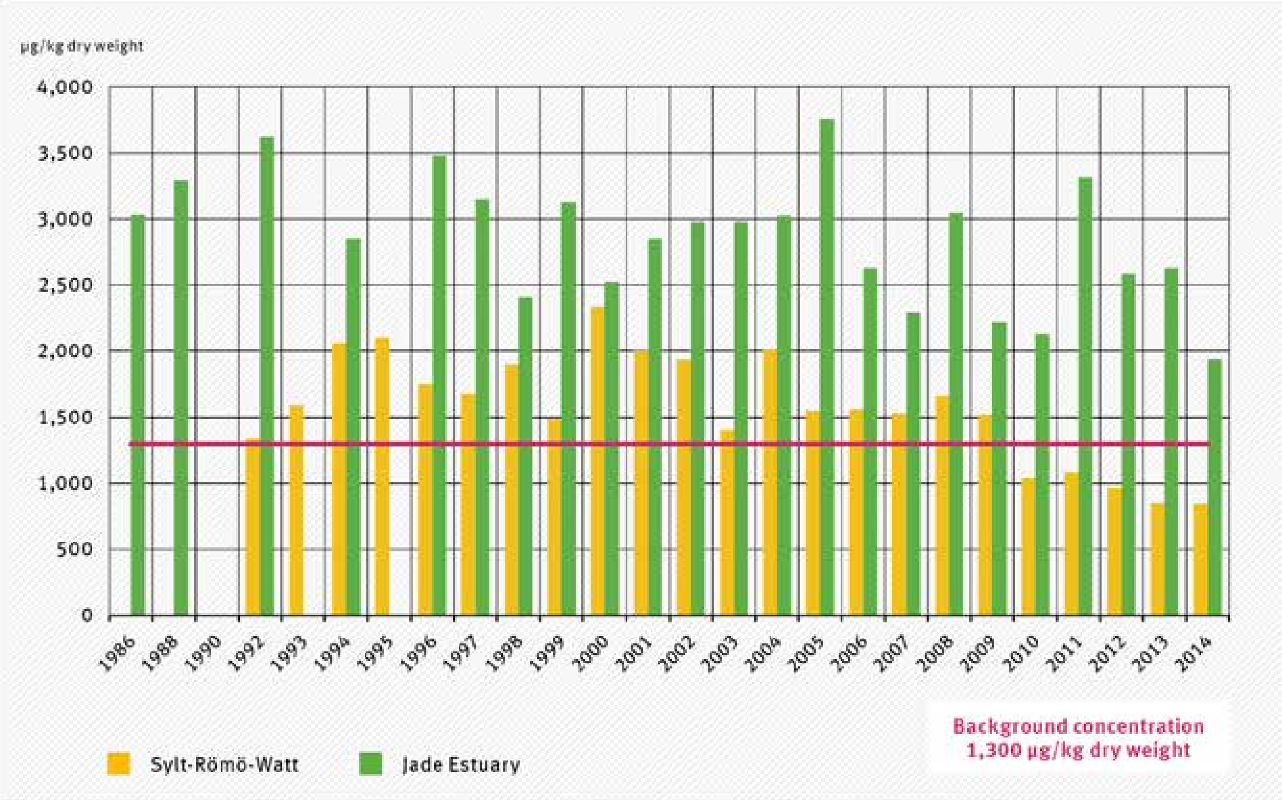
Name of substance	Concentration range (min – max) in µg/kg (fresh weight)*	Biota EQS in µg/kg (fresh weight)
Mercury	6 – 52	20
Dicofol	‹ 0.02	33
Brominated diphenyl ether	0.018 – 0.07	0.0085
Hexabromocyclododecane	‹ 0.2 – 2.9	167
Hexachlorobenzene	0.025 – 0.043	10
Hexachlorobutadiene	‹ 0.02	55
Perfluorooctanesulfonic acid	‹ 2.0 – 5.72	9.1

* Fish species analysed: Perch, bream, eel-pout

Source: LUNG 2016

Figure 68

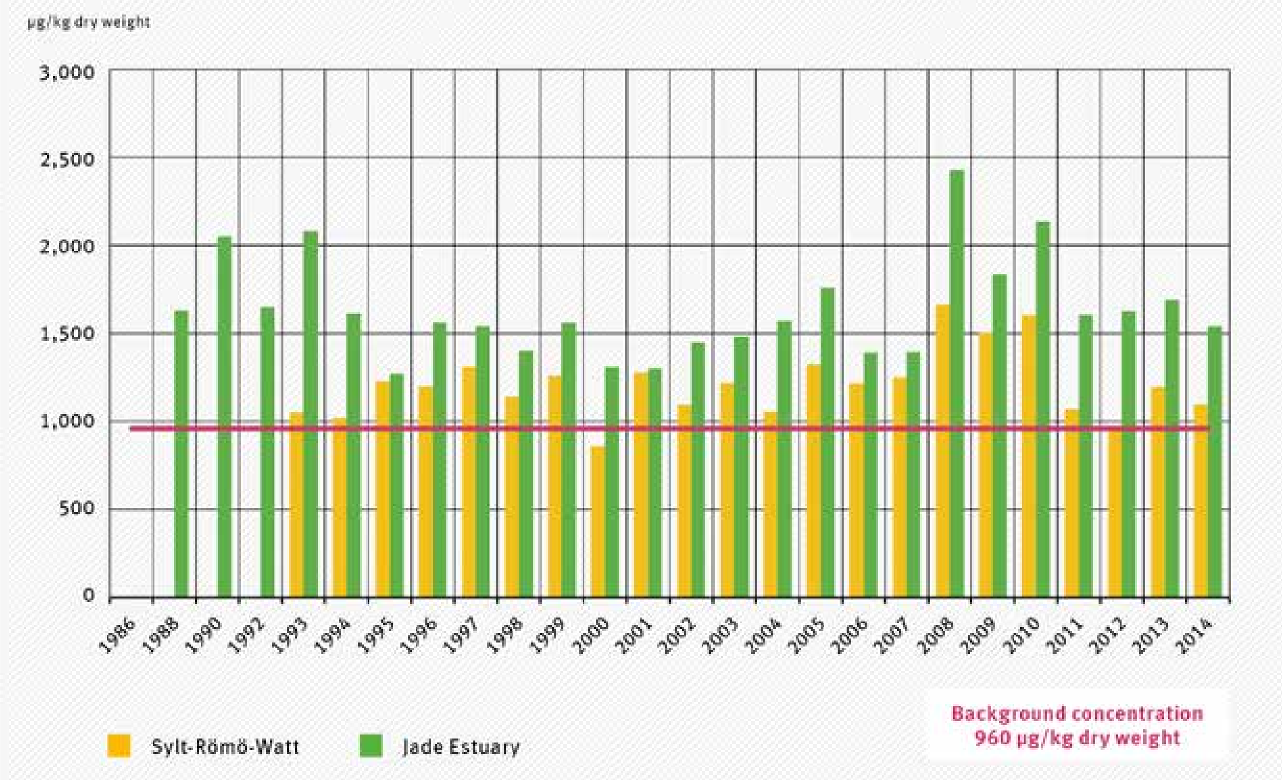
Lead in common mussels



Source: German Environment Agency, Environmental Specimen Bank, 2016

Figure 69

Cadmium in common mussels



Source: German Environment Agency, Environmental Specimen Bank, 2016

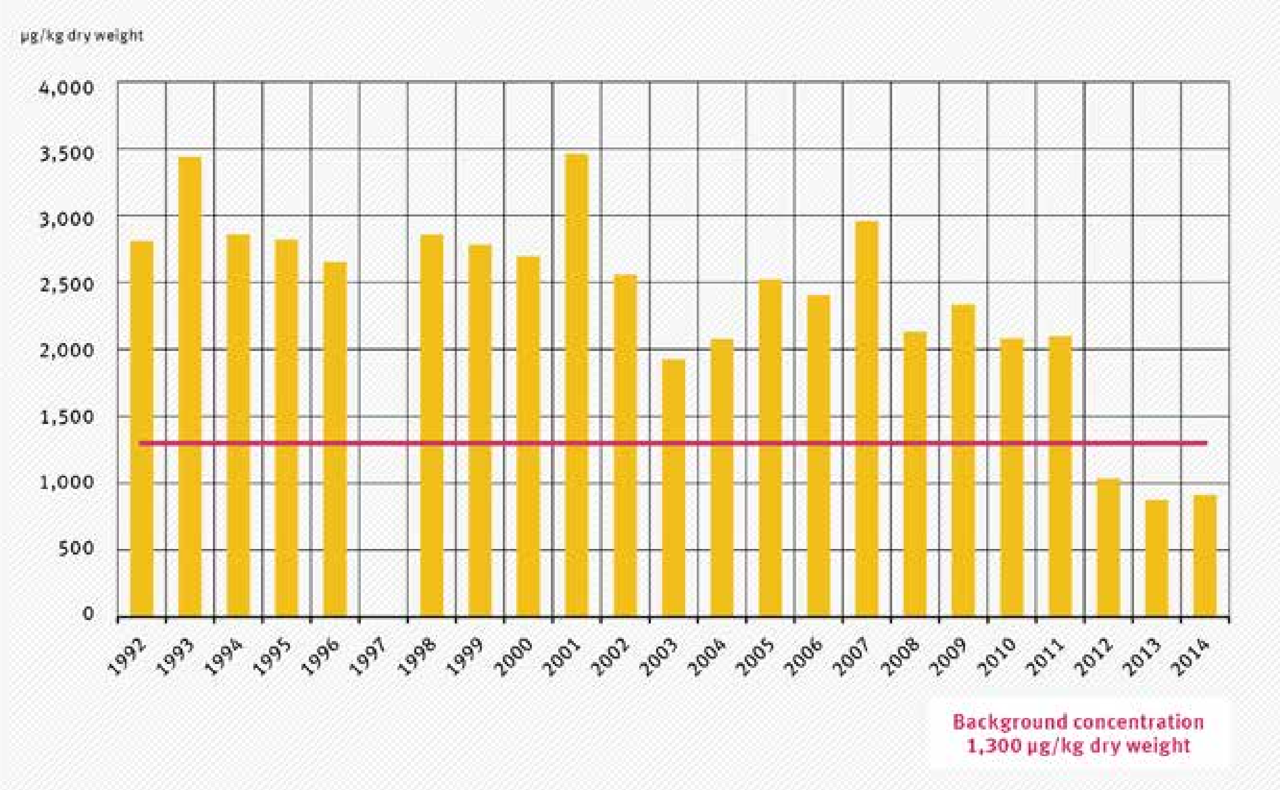
Figure 70

Mercury in eel-pout muscle tissue

Source: German Environment Agency, Environmental Specimen Bank, 2016

Figure 71

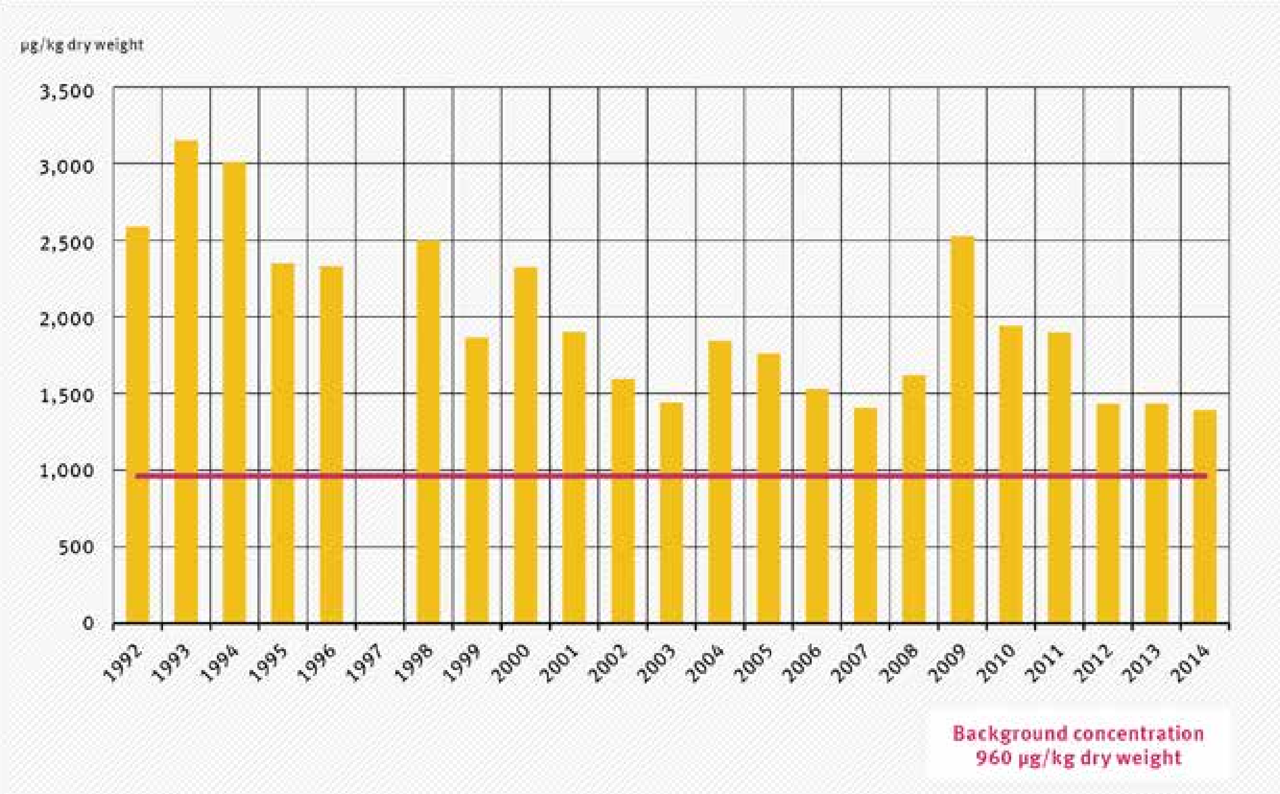
Lead in common mussels (Darßer Ort)



Source: German Environment Agency, Environmental Specimen Bank, 2016

Figure 72

Cadmium in common mussels (Darßer Ort)



Source: German Environment Agency, Environmental Specimen Bank, 2016

In muscle flesh from eel-pout from the Jade Estuary and Meldorf Bight, the analysed concentrations of mercury significantly exceeded the biota-EQS for fish over the entire monitoring period (Figure 70).

Contamination of fish and mussels from the Baltic Sea off Darßer Ort with heavy metals also decreased over the monitoring period. In some cases, however, concentrations remain above the Background Assessment Concentrations (BAC) derived by OSPAR, which are also used by HELCOM as assessment thresholds (Table 28).

Lead levels in common mussels at the Darßer Ort monitoring sties have decreased by around 70 % since 1992, and are now considered safe for human consumption (Figure 71). In 2014, common mussels from the Baltic Sea coast off Darßer Ort still had cadmium levels slightly above the BAC. Since 1992, however, levels have dropped by more than half (Figure 72).

Over the entire monitoring period 1994 to 2014, mercury concentrations in the muscle tissue of eel-pout exceeded the biota-EQS for fish (Figure 73).

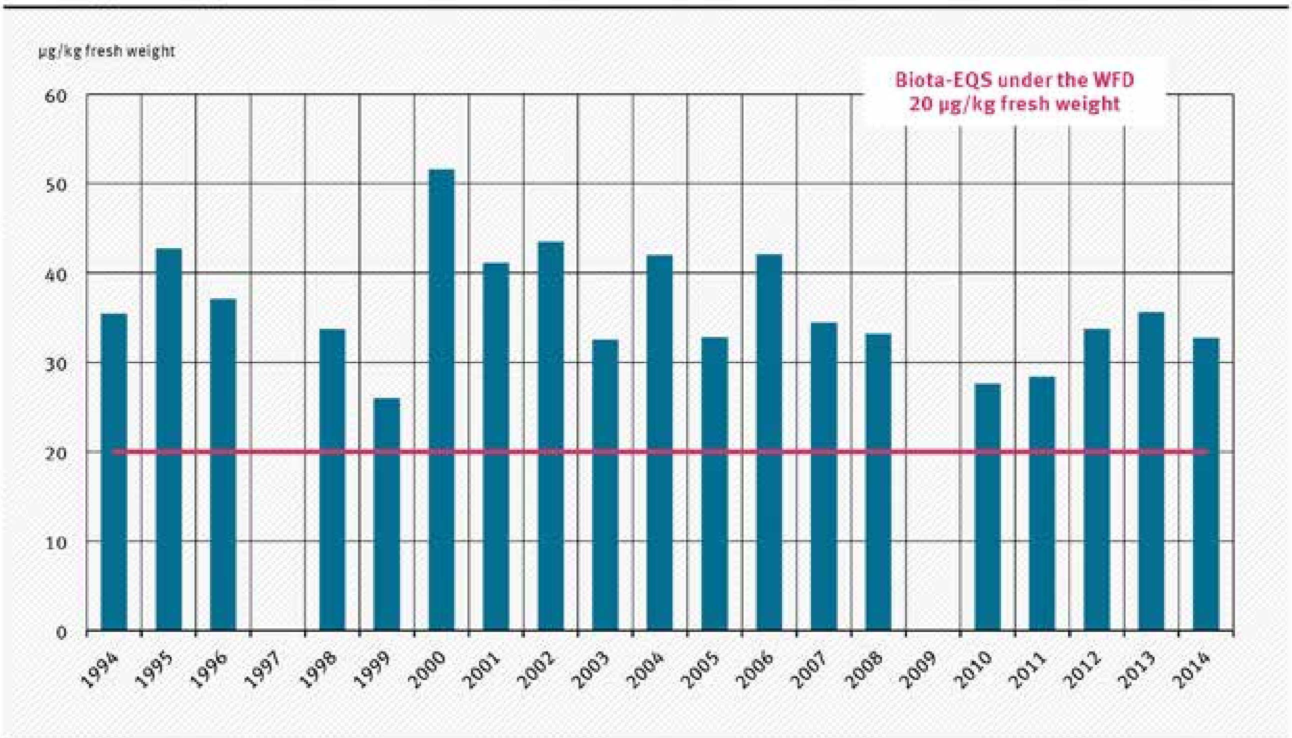
7.2.2.2 Organic compounds

Marine waters act as sinks for chemicals that resist degradation. This prompted OSPAR and HELCOM to commit to the target of eliminating inputs, emissions and losses of these substances into our seas within a generation. The Water Framework Directive adopted the same target for priority hazardous substances (chapter 4.2.3). For nine of these substances that accumulate heavily in organisms, the Ordinance on Surface Waters defines EQS for biota (see chapter 4.2.3). Eel-pout from the three sampling zones on the North and Baltic Sea coast generally are only slightly polluted by dioxins and dioxin-like substances, hexabromocyclododecane (HBCDD) and perfluorooctane sulfonate (PFOS). These substances are also chosen as indicators for the assessment of good environmental status in one or both marine regions. In 2015, concentrations of HBCDD and PFOS were below the respective biota-EQS (see https://www.umweltbundesamt.de/daten/gewaesserbelastung/nordsee/schadstoffkonzentrationen-in-organismen-der-nordsee; https://www.umweltbundesamt.de/daten/gewaesserbelastung/ostsee/schadstoffkonzentrationen-in-organismen-der-ostsee). However, in the case of heptachlor and its degradation product heptachlor epoxide, the precision of the chemical analysis is insufficient to be able to verify compliance with the EQS.

Small highland river close to the source
Source: Stephan Naumann

Figure 73

Mercury in eel-pout muscle tissue (Darßer Ort)



Source: German Environment Agency, Environmental Specimen Bank, 2016

Polybrominated diphenyl ether (BDE)
BDE was used as a flame retardant up until the 1990s. Since 2004, the manufacture and use of BDE, for which EQS have been set under the Water Framework Directive, has been banned across Europe. Although concentration levels in eel-pout muscle tissue have decreased sharply since then, in 2015 they were significantly higher on the German coast than the EQS for fish (Figure 74).

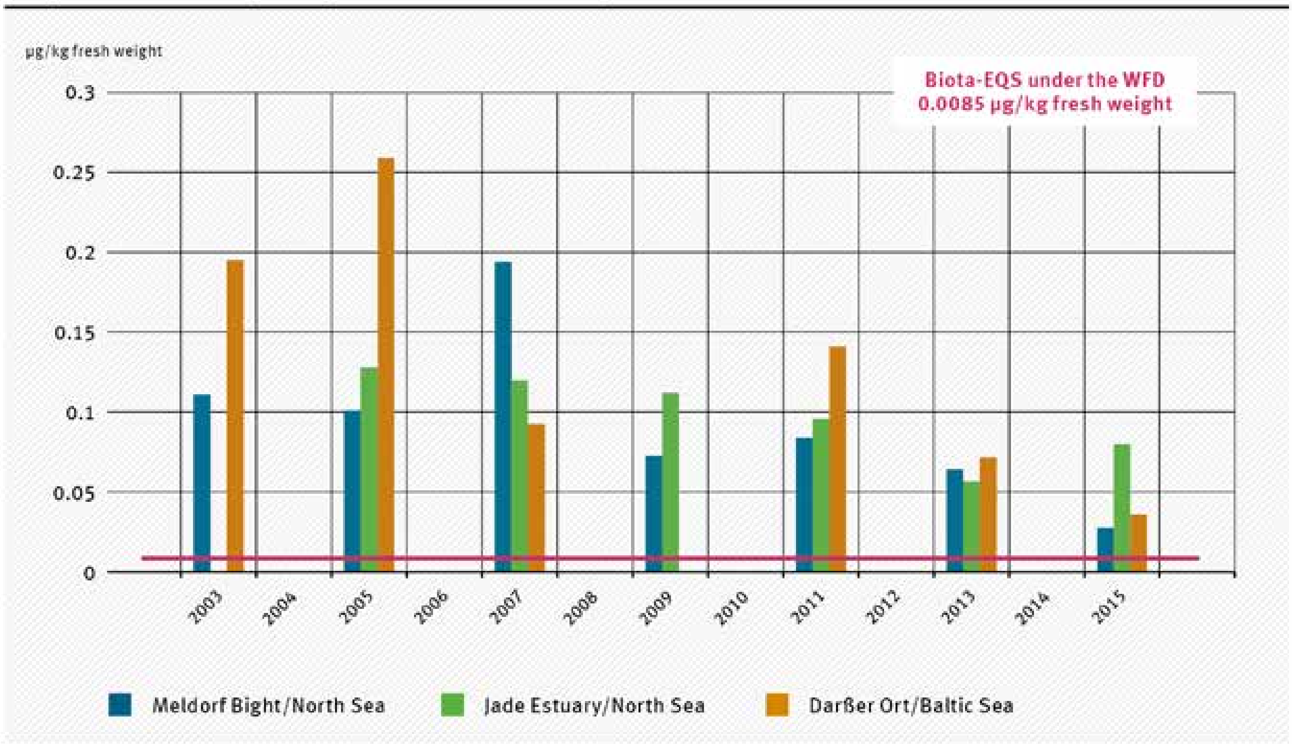
Tributyl tin compound
The organic tin compound tributyl tin (TBT) had primarily been used as biocide in underwater ship's coatings to prevent the growth of mussels, barnacles and algae. The persistent TBT released from these coatings pollutes many seas and rivers due to its effect as an environmental hormone. For the North and Baltic Seas, TBT is measured as an indicator of good environmental status and is a priority hazardous substance under the Water Framework Directive. Since 1989, TBT has been banned from use in Germany in antifouling coatings of vessels below a length of 25 m. In 1990 a European-wide ban followed, which in 2003 was extended to organotin compounds in antifouling coatings for all types of vessels.

Specimens from the Environmental Specimen Bank prove that TBT concentrations in common mussels remained relatively constant between the mid-1980s and the end of the 1990s. The ban on TBT for smaller vessels, in force since 1989/1990, has evidently had no effect. Only when the general ban on organotin compounds entered into force in 2003 TBT levels on common mussels did show a significant decrease.

OSPAR and HELCOM specify the effect-based assessment threshold (Environmental Assessment Criteria (EAC)) for TBT in common mussels at 12 µg/kg dry weight. Until 2006, TBT levels in common mussels from the sampling zones of the North and Baltic Seas were several times higher than this. Since then, pollution levels in mussels have decreased sharply, and since 2008/2009 (North Sea) and 2011 (Baltic Sea) have been below the assessment threshold (Figure 75).

7.2.3 Marine litter
The pollution of our oceans with litter is seen as one of the most pressing global environmental problems, alongside other key issues such as loss of biodiversity, climate change and ocean acidification (Sutherland et al. 2010). The term "marine litter" refers to all long-lasting, manufactured or processed durable materials that enter the marine environment as discard or as ownerless commodities. This includes transport into the oceans via rivers, discharges and the wind (Galgani et al. 2010). Alongside large-format litter such as plastic bottles and

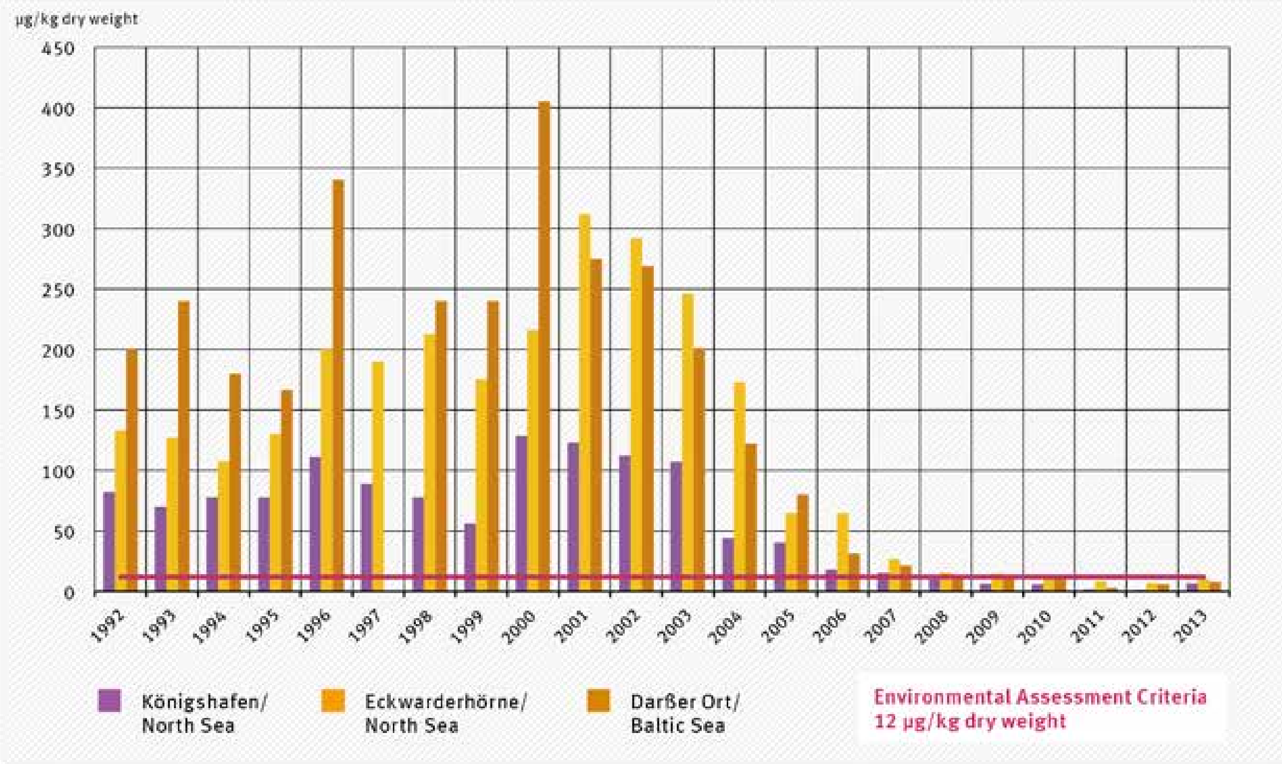
Figure 74
Polybrominated diphenyl ether (BDE) in eel-pout muscle tissue



Source: German Environment Agency, Environmental Specimen Bank, 2016

Figure 75

Tributyl tin in common mussels



Source: German Environment Agency, Environmental Specimen Bank, 2016

plastic bags, micro particles are also sighted in the marine environment (a mirco particle is defined as a piece of litter of 5 millimetres or less), and increasing levels are being detected in marine organisms.

The MSFD calls for an assessment of the pollution of Germany's marine regions with marine litter based on the indicators "amount" and "properties" of litter on the beach/along the drift line, on the sea surface, on the sea floor; other indicators are micro-litter as well as related biological impacts. Descriptor 10 of the Marine Strategy Framework Directive defines good environmental status on the basis of types and quantities of marine litter and their decomposition products considered harmless to marine organisms and habitats.

Litter on the beach/along the drift line

During the analysis period 2009–2014, a consistently high level of marine litter was ascertained in the North-East Atlantic including the North Sea. On average, there are 380 pieces of litter per 100 metres of coastline on the southern North Sea beaches that are monitored. As in the preceding analysis period (2002–2008), not identifiable plastic and polystyrene fragments, together with fishing nets, ropes, lines and cords, predominate, each accounting for approximately one-third of the total. These are followed by plastic lids and seals from beverage packagings (7 %). Other findings include plastic drinking bottles, disposable food packaging, sweet and snack wrappers, lolly sticks and shopping bags. Balloon (cords) and rifle cartridges also make it into the top 15. All this litter may be harmful to marine fauna due to the possibility of entanglement/strangulation, ingestion and injuries (OSPAR 2017, in publication).

Along the Baltic Sea, in the period under review (2010–2015), an average of 68 pieces of litter per 100 metres of coastline were ascertained at 29 beaches, with major regional and seasonal differences of between seven and 404 pieces. 69 % of findings were plastic. 35 % were found in the spring months, and only minimal levels in the winter months. Not identifiable plastic fragments of less than 50 centimetres dominated, accounting for around 30 %, followed by cigarette butts (9 %), plastic lids and seals from beverage packaging (7 %), sweet wrappers (4 %), plastic cords/ropes/lines (3 %), plastic bevarage packaging (3 %), small plastic bags (3 %) and single-use plates (2 %) (State Agency for the Environment, Nature Conservation and Geology/Landesamt für Umwelt, Naturschutz und Geologie, LUNG 2015).

Litter on the sea surface/in seabirds

The widespread Northern fulmar is used to monitor litter on the surface of the North Sea, as it feeds exclusively on the open seas. The contents of the stomachs of Northern fulmars found dead on the German North Sea coast are analysed, and any plastic particles are counted and weighed. The indicator is calculated as an average over five years.

In 2008, OSPAR Contracting Parties agreed on a target value within the context of a corresponding ecological quality objective, which stated that no more than 10 % of all Northern fulmars found dead should contain more than 0.1 grams of plastic in their stomachs. This figure was derived from the comparatively unpolluted Canadian Arctic. Since studies began in 2000, plastics have been found in 93–97 % of the stomachs of Northern fulmars that are found dead; in 60 % of cases, the quantity of plastics exceeded 0.1 grams. Among the findings, consumer waste predominates with 80 % (all non-industrial parts of plastic objects such as fragments of larger parts), while the remaining 20 % is attributable to industrial plastic (granulates/pellets) (OSPAR 2017, in publication).

Litter on the sea floor

This indicator is based on trawling net surveys, originally designed for sampling benthic marine biota for research purposes over a range of different sea floor types. Parallel to this, marine litter is collected and assessed. For the analysis period 2011–2015, a wide dissemination of litter with a north-south gradient was found on the sea floor of the North Sea, which was dominated by plastics. Throughout the entire southern North Sea, average benthic litter densities of 6.35 ± 11.5 kg/km² were ascertained. Pollution of the sea floor in the North Sea is not decreasing, since existing litter is only periodically re-suspended due to storms (OSPAR 2017, in publication).

7.2.4 Underwater noise

Natural noise sources such as wind and wave movement form the background noise in the ocean. This natural "acoustic landscape" is supplemented by continuous anthropogenic noise emissions. As continuous emissions, they raise the natural ambient noise level, and as impulsive signals they temporarily increase the noise level in a marine region. Impulsive underwater noise includes sonar, noise-intensive construction work for offshore wind farms, seismic activities, explosions (e.g. from dumped munitions) and the use of acoustic deterrent devices e.g. in fishing. Shipping, sand and gravel extraction and the operation of offshore wind farms are the principal sources of continuous noise emissions.

Water is a good transport medium for sound, because acoustic waves propagate four times faster in water than in the air. Particularly impulsive sound emissions may result in damage to marine species. Continuous noise sources, on the other hand, have different effects, such as disturbance (causing the affected species to move away) or masking of biologically important signals.

Marine organisms vary widely in their sensitivity and hearing powers. Despite many unquantifiable factors, a number of studies have now shown that underwater noise damages marine organisms and may impair their vital functions. As such, it is essential to protect them from death, injury and significant disturbances, as prescribed by national and international law. Alongside marine mammals, this also affects fish and invertebrates such as crabs, squid, mussels and gastropods. Particularly in their early development stages, a number of species are highly sensitive to noise signals.

One key policy mechanism for addressing the issue of underwater noise is the ongoing implementation of the Marine Strategy Framework Directive, which states that the introduction of energy, including underwater noise, must not be allowed to have an adverse effect on the marine environment. Being relevant indicators, the temporal and spatial distribution of loud impulsive noise at low and medium frequencies, as well as persistent (continuous) noise at low frequency are to be monitored, and the impacts to be evaluated. Monitoring of both these indicators is currently being developed, with a national register providing the basis for the first indicator, which clearly shows when relevant impulsive noise events (pile-driving for offshore wind farms, sonar, seismic activities and explosions) occurred over the course of the year. Technical options for noise reduction can also be taken into account. The German Environment Agency is currently funding a research and development project to implement pilot monitoring of the ambient noise level with due regard to relevant continuous noise emissions (particularly from shipping) at selected points in German seas, which is intended to provide the basis for long-term monitoring of the second indicator. Because monitoring is currently under development, the two indicators cannot yet be comprehensively assessed; however, statements can be made regarding the resultant pressures on marine organisms. The data collated and compiled in recent years also permit the initial assessment that neither of these indicators has a good environmental status.

One noise source is already regulated: The German energy concept provides for the intensive expansion of offshore wind energy, and over the next few years, pile-driving used in the construction of offshore wind farms will therefore generate significant underwater noise in Germany's marine regions. It takes between 5,000 and 10,000 pile-driving strokes to anchor the foundations of these turbines in the ocean floor emitting sound energy of up to 220 decibels. In December 2015, there were 815 individual turbines on-stream in Germany with a total energy output of 3.3 gigawatt. In order to achieve the energy transition, the German Government plans to feed some 15 gigawatts generated from offshore wind energy into the grid by 2030, necessitating intensive construction work at sea over the next few years. This poses a serious problem for Germany's only indigenous species of whale, the harbour porpoise, which can suffer irreversible hearing damage or even deafness as a result, and may also be driven out of key habitats. In order to prevent auditory damage to porpoises, therefore, Germany already has in place the dual noise protection level recommended by the German Environment Agency, of 160 decibels for a single noise event and 190 decibels for the peak noise level at a distance of 750 meters. Since 2008, this value has been binding for every new wind turbine installation and requires the use of technical mitigation measures (such as an air bubble curtain or cofferdam), which helps to maintain equilibrium between climate protection and species conservation (Müller & Werner, 2015).


8

8 Summary and conclusions

The EU Water Framework Directive (WFD) formulates ambitious targets for the protection of groundwater and surface water. Germany's management plans, updated in 2015 (Article 13 of the WFD), provide evidence for the progress made towards reaching these targets. At the same time, they also show that additional measures are needed to achieve good status of waters.

Due to excessive nitrate pollution, only 64 % of groundwater bodies used as main drinking water resource are in good chemical status. Nitrate pollution must be reduced as a matter of urgency, also to avoid efforts and costs of drinking water treatment. The quantitative status is good for 96 % of groundwater bodies.

Only 9 % of the course of natural rivers and brooks exhibit good or high ecological status. Among heavily modified water bodies such as dams and artificial water bodies, only 2.2 % and 5 % respectively indicate good ecological potential. Improvements are needed with regard to morphological structure, continuity for fish and smaller organisms, nutrient contamination, and pollution with chemicals.

For lakes, the results are more encouraging: 26.3 % of 732 lakes in Germany achieve good or high ecological status, or good ecological potential. Among transitional and coastal waters, none of the 80 water bodies exhibits good ecological status. The greatest pressure factor are nutrients discharged into these water bodies by rivers, leading to eutrophication.

The chemical status of surface waters is assessed based on the EU environmental quality standards for priority substances. The chemical status is "not good" throughout, because the environmental quality standard for mercury in biota is exceeded nationwide. For other priority substances, the situation is by far different.

Like the WFD, the EU Marine Strategy Framework Directive (MSFD) is ecologically driven, and also aims at achieving or maintaining good status of water bodies. The status of the marine ecosystems is assessed using an integrative ecological classification which makes allowance for pressures from invasive species, commercial fishing, eutrophication, pollutants, litter and inputs of energy (such as cooling water and noise).

The status assessment for all water bodies confirms that further measures are needed to meet the objectives of both the Water Framework Directive and the Marine Strategy Framework Directive. With respect to rivers, hydromorphology needs to be improved, and in all water categories, concentrations of nutrients, pesticides and metals must be reduced.

Hydromorphological status can be improved by restoring the course of the river and removing bed and bank fortifications, connecting bayous, relaying dykes, and raising beds. Longitudinal continuity would give the aquatic fauna access to functioning habitats. Such continuity can often be restored without restricting usage. Careful water body maintenance can help to improve ecological status with a diverse range of small-scale measures. It is advantageous to "let the water take its course", provided no disadvantageous impacts on usage are anticipated. In the longer term, only those hydromorphological changes which are necessary in order to maintain ecologically compatible uses should be retained.

Inputs from agricultural land – in the case of phosphorus from eroded soil material and drainage, and in the case of nitrogen from agricultural surpluses via the groundwater – are largely responsible for the high nutrient loads of groundwater, rivers, lakes, coastal and marine waters. These are also the areas with the greatest reduction potential.

Even if the positive trend of falling nutrient inputs continues, the eutrophication effects in coastal and marine waters will only respond with a delayed effect. In the Wadden Sea and in many regions of the Baltic Sea in particular, nutrients in sediment deposited in the past will persist for a long time. Moreover, in future, eutrophication processes could be further encouraged by climate change because stratification in water bodies intensifies due to the warming of surface water. In northern latitudes, furthermore, more frequent and more extreme rainfalls are anticipated, which may lead to increased nutrient inputs.

Among pollutants, chemicals, pesticides and pharmaceuticals with poor degradability are of special concern. Some pesticides exceed the environmental quality standards for surface waters and the quality standards for groundwater. In groundwater close to the surface, 5 % of more than thirteen thousand monitoring points fail to meet the limit of 0.1 µg/l for at least one active ingredient.

Fish in rivers, lakes and marine waters are highly polluted with polybrominated diphenyl ethers. In rivers, the environmental quality standards for polycyclic aromatic hydrocarbons and tributyl tin are frequently exceeded. The tributyl tin concentrations in mussels from the North and Baltic Seas have been decreasing since 2002, because TBT containing ship's paint have been banned since 2001.

In some cases, the pollution of surface waters with mercury and cadmium has significantly decreased over the years. Nevertheless, the quality standards are still being exceeded, and more extensive reduction measures are therefore needed. Tin and copper are predominantly discharged into water bodies by rainwater running off roads and roofs.

Up to now, the EU has not adopted an environmental quality standard for pharmaceuticals yet, but concentrations of the widely used active ingredients diclofenac and ibuprofen very often exceed the proposed levels in flowing waters.

Pollution of our seas with litter and noise are two comparatively new issues addressed by the MSFD. With this in mind, the signatories to the regional sea conventions (OSPAR, HELCOM) work on both the establishment of a sustainable monitoring system and the development of techniques for assessing the impacts of litter and noise on marine ecosystems. Findings to date are already considered sufficiently worrying with the result that the German MSFD programme of measures contains initial proposals (see below).

Ambitious goals demand ambitious measures, which have already been addressed by the WFD management plans and updated in 2015 (see brochure "The Water Framework Directive – The status of German waters 2015"). They were supplemented in particular with the 2016 MSFD programmes of measures on marine litter and marine pollution by fishing and shipping. However, there is still much to be done. There are already today indications that Germany's coastal and marine waters will not meet good environmental status under the Marine Strategy Framework Directive by 2020, and even by 2027, not all water bodies will have achieved good status as defined in the Water Framework Directive. Therefore, the management cycles of both Directives should be continued with undiminished aspirations in order to achieve a good quality of waters in marine and inland waters.

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