# Germany

## Environmental challenges for the Hamburg stretch of the River Elbe and its catchment with regard to the Water Framework Directive

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watersketch

## Content

## Abstract

The part of the Elbe that flows through Hamburg will not comply with the objectives of the Water Framework Directive in terms of river morphology, ecological and chemical criteria. Due to the demands and activities of the Port of Hamburg, the river has been morphologically modified in terms of navigational depth and container transfer. But the lower Elbe is also characterised by the impacts of former storm surges that have led to the extensive embankment of the river. All these activities have created a river system, in which shallow areas are reduced and the volume of light-limited and anoxic waters increases, leading to increasing oxygen depletion in summer. Even though the quality of the Elbe water has improved during the 1990s, this oxygen depletion threatens the partially recovered fish diversity in the area.

Measures discussed to improve the situation include the maintenance and support of shallow water areas, in which oxygen is produced by phytoplankton organisms, and the further reduction of nutrient emissions into the Elbe River in order to reduce the overall mass production that causes the oxygen-demanding degradation process at the river bottom. Measures that increase the dysphotic water bodies, such as further river deepening plans and relocation of dredged material in the zone sensitive to oxygen depletion, are controversially discussed in this respect.

Morphological changes are also discussed as one reason for increasing sedimentation in the harbour area. As this material is mostly contaminated, it is subject to restrictions in terms of handling and treatment. The increase in sediment that needs to be dredged has reached an extent that threatens the existence of the port, so that short-term solutions needed to be found. Disposal in the North Sea is the option currently carried out. To some extent adverse impacts are to be expected and conflicts will arise with regard to compliance with the WFD as this measure opposes the non-deterioration principle.

The main reason for the persisting contamination of sediment in the Elbe River has been identified as a legacy of past upstream pollution in the Czech Republic and in the area of the former GDR. Even though industrial emissions probably also need to be reduced in Hamburg itself, a prioritization of sites would show that measures would be most effective if applied in the areas upstream. Financial constraints of the Federal States in which these sites lie, make implementation of solutions difficult. A river basin approach with – also financial - cooperation of all stakeholders beyond political borders is required in order to solve historical contamination and in order to address the interactions between different sites in a river basin.


## 1 Introduction

The quality of the Elbe in Hamburg is influenced by the industrial and political history upstream, by emissions of the big city with extensive industrial activities, by the morphological changes due to the construction and maintenance of Germany's largest port, and by the tides that strongly affect the sediment dynamics in Hamburg.

Sediments are an important topic in Hamburg – because of their quantity and their quality. These sediments originate partly from upstream, but to the greatest extent from the North Sea. They settle in still water zones of the port, e.g. harbour basins, from where they have to be actively removed in order to maintain navigational water depth. As sediments tend to accumulate contaminants, a large volume of what needs to be dredged in Hamburg cannot be relocated to the sea but needs to be treated or disposed of on land at high expense. Therewith, the quality of sediments is an economic factor. Naturally, it is also of environmental importance, as contaminants can be remobilised when sediments become resuspended – by natural events such as floods or by anthropogenic activities like relocation of dredged material. Even though their quality has been given little attention in the Water Framework Directive, they ought to be considered as a secondary source of pollution, which needs to be addressed and for which measures need to be suggested in River Basin Management Plans. For Hamburg any such measures will be of little use when limited within the boundaries of the city, as the main problems derive from upstream in terms of quality and from the North Sea in terms of quantity. Even though Hamburg also necessarily has its own share in causing environmental problems, long-term solutions can only be found in the sustainable management of the whole river basin, which requires community-supported long-term strategies that are aware of and address the different interests, uses and functions in the catchment area – from the upper Elbe to the estuary.

# 2 Background information

## 2.1 The current situation

### 2.1.1 The Elbe

The Elbe River is one of the major rivers in Western Europe. From its spring in the Giant Mountains ("Krkonoše Mountains", Czech Republic) to its mouth at the North Sea near Cuxhaven (Germany) it covers a distance of 1,091 kilometres and a catchment area of 148,268 km2 – one third of it located in the Czech Republic and two thirds in the Federal Republic of Germany, smaller areas belonging to Poland and Austria. Along its way the catchment drains some of North and Central Europe's major cities including Prague, Dresden, Berlin and Hamburg. The Elbe River flows through Bohemia, the Elbe Sandstone Mountains and drains the Ore Mountains before it reaches the Middle and North German Lowland. The Mulde flows into the Elbe at river-km 260 (from the Czech-German border), Schnackenburg at the former East-West German border is at river-km 480, Hamburg at river-km 620 and the North Sea at approx. river-km 730. Downstream of the weir in Geesthacht, the river is influenced by the tide for more than 100 km until it flows into the North Sea at Cuxhaven. In this area the Port of Hamburg is situated. With respect to the WFD the Elbe River basin consist of three different types of waters, river, estuary and coastal water.

as discharge system for various industrial and municipal purposes. Waste water was released untreated into the river system in former East Germany (GDR) and Czechoslovakia. These contaminants nowadays form a "legacy of the past" as they are enriched in the Elbe sediment and transported downstream when resuspended. This is expected to influence the achievement of the objectives of the WFD (Heise et al, 2005).

For the implementation of the Water Framework Directive, the Elbe River Basin has been divided into 10 coordination areas (Fig. 2). The upper and middle Elbe (HSL), the upper Moldau/Vlatava (HVL), the Berounka (BER), the lower Moldau/Vlatava (DVL), the Eger and lower Elbe (ODL), Mulde-Elbe-Schwarze Elster (MES), Saale (SAL), Middle Elbe/Eide (MEL), Havel (HAV) and the Tidal Elbe (TEL). This report focuses on the Tidal Elbe including its major city Hamburg.

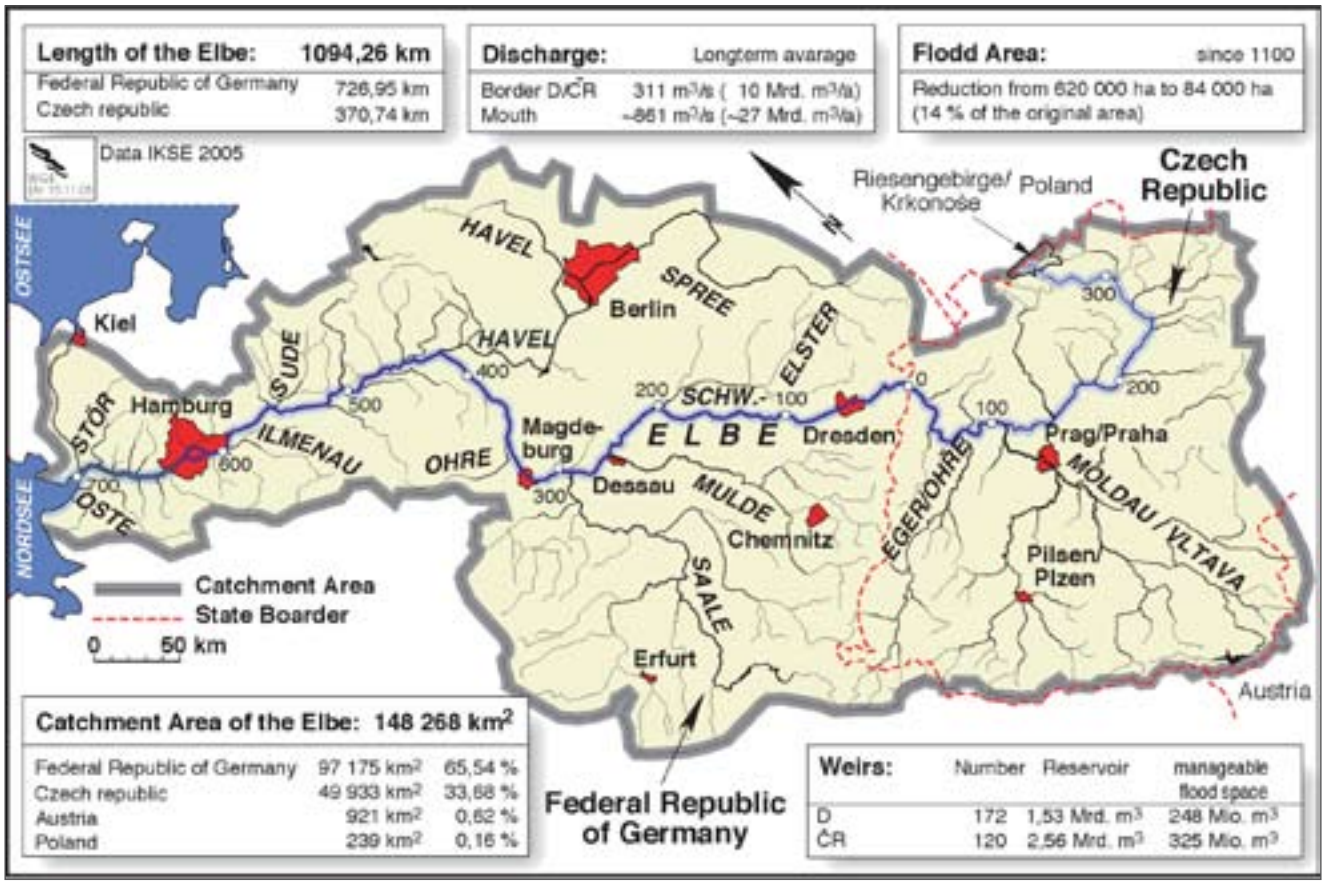


Fig.1: Characteristics of the Elbe Catchment Area (Image: ARGE-Elbe)

The most important tributaries of the Elbe River with respect to the total amount of water and contaminants are Havel, Saale, Elster, Mulde, Moldau and Eger.

During the 1970s the Elbe River was one of the most polluted rivers in Europe. Especially during the time of the iron curtain, the Elbe River and their tributaries were used


Fig. 2: WFD-coordination areas of the Elbe catchment (Image: IKSE)

## 2.1.2 Hamburg as part of the Elbe Catchment

With 1.7 m inhabitants Hamburg is the second largest city in Germany and its 3rd largest industrial area, comprising automobile industry, precision engineering, mechanical engineering, chemical production, metal industry, and oil processing industry. The most important industry in Hamburg, however, is the harbour - in terms of international reputation, employment and income for Hamburg.

Fig. 3: View over parts of the Hamburg Harbour area (Image: Wassergütestelle Elbe)

Directly or indirectly, 131.000 people are employed in Hamburg in connection with harbour activities adding up to 12.6 % of all jobs in Hamburg (Freie und Hansestadt Hamburg, 2006). Accordingly, the harbour is of high economical importance for the city.

Immigration, economic growth and an employment increase at the beginning of the 1990s led to a rise of the region around Hamburg to one of the most important German Metropolitan regions.

Borne from the realisation, that increasing economical demands and challenges could not be tackled by one Federal State alone, Hamburg agreed with its adjacent neighbours, Lower Saxony and Schleswig-Holstein, to increase cooperation in the metropolitan region, to create a common job market and a unified economical region. The "Metropolregion Hamburg" now comprises 800 cities and municipalities and 4.2 m inhabitants (Metropolregion Hamburg, http:// homepage.hamburg.de/redaktionhh/metropolregion/Broschuere_zur_Metropolregion)

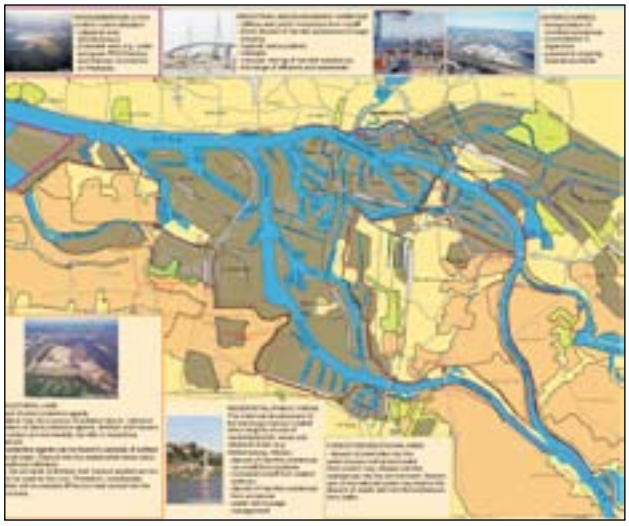

Fig. 4: Land use in Hamburg (Image Watersketch)

Open air space and buildings: 36%

Agriculture: 27%

Traffic area 12%

Lakes, rivers and canals 8%

Recreational areas 12%

Others 5%

10% of the area is used in connection with harbour activities.


Fig. 4 depicts the land use in Hamburg. For a large part the two Elbe sections, the Northern and the Southern Elbe River, are surrounded by industrial areas. The surface area that is taken up by activities related to the harbour function makes up approximately 10 % in Hamburg. It is mainly the south-east area directly after the division of the Elbe river into the two sections and the region North of the Northern Elbe, which are used for living and recreational purposes. It should be stressed that extensive agricultural areas are located south-east of Hamburg (z.B. "Vierlanden") and downstream of Hamburg ("Altes Land").

## 2.1.3 Hamburg and the Tideelbe

Like all rivers that are influenced by the tides the estuary downstream of Hamburg shows an area of high turbidity (Fig. 5).

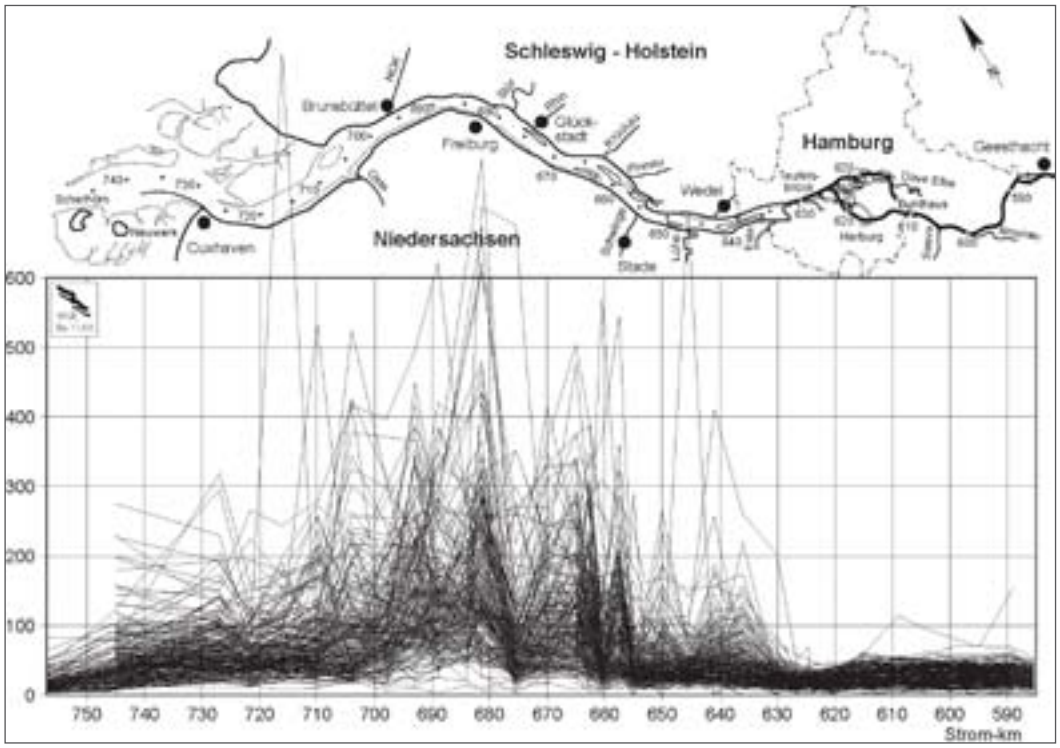


Fig. 5: Longitudinal profiles of suspended matter along the tidal area downstream of Hamburg between 1979 and 2003 (from Bergemann, 2004)

The high concentration of suspended matter results from a net transport from the North Sea upstream towards Hamburg. Its extent varies with the tides, the morphology of the river, the river discharge and the composition of suspended matter (Bergemann, 2004). During times of low water discharge of the Elbe, the turbidity increases and material is transported towards Hamburg. Flood events in the catchment on the other side can "push" suspended matter into the North Sea. The turbidity maximum and sediment dynamics in the tidal area are of high economical importance. The solid matter that is transported to Hamburg from the North Sea increases the amount of material that settles in the harbour basins and therewith the volume of material necessary to be dredged to maintain navigational water depth. On the other side, this material is relatively little contaminated and dilutes the contaminant concentration that is introduced to the harbour with the Elbe from upstream. Hence, hydrodynamics of the river and the extent of mixing of estuarine with fluvial sediments affect the categorisation of dredged material in terms of fate of treatment.

## 2.1.4 The ecological situation of the Elbe in Hamburg

The ecological situation in Hamburg is influenced in terms of chemical quality by the dissolved or – more importantly – particle bound contaminants that are transported towards Hamburg by the Elbe. It is also influenced by industry emissions within the Hamburg Area. For 2001 the EPER[1] listed four industrial plants in Hamburg that emitted notifiable concentrations, such as 1,2-dichlorethane, phenol compounds, arsenic, cadmium, copper, nickel, lead and zinc into surface waters. The relative contribution of these sources to the contamination of water and sediment within Hamburg is difficult to estimate due to the high immission in the Elbe upstream of Hamburg. A recently prepared report for the Hamburg Port Authority lists the different areas of concern along the Elbe River with regard to the extent of their contamination (Heise et al, 2005). A comparative risk analysis that would quantify the contribution of sources to downstream regions has not yet been performed but has been planned.

Another important factor that affects the ecology within the Hamburg Elbe area is the morphology of the river and how it has been altered. Long-term modifications of the river, e.g. deepening of the stream, building of dikes and river embankments etc. have led to extensive challenges in water current velocity, transport and sedimentation patterns of material and tidal ranges. Effects on the macrozoobenthos community, algae growth and fish diversity are strongly suspected (see below).

The results of the first monitoring for the WFD that was supposed to give an indication on which areas will achieve the quality norms of the WFD and which will probably fail, is presented in Table I. No difference between the four water bodies that are differentiated along the Tidal Elbe can be observed. The objectives of the WFD will only be achieved where water supply and free passage of water bodies are observed. All water bodies are therefore likely to fail all other criteria.

[1] European Pollutant Emission Register

| Waterbody | Biological quality components | | | | Hydromorphological quality components | | | Physical-chemical quality components | | Integrative assessment | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | phytoplankon | Macrophytes and phytobenthos | Benthic invertebrates | fishes | Water supply | Passability | Morphology | General conditions | Specific contaminants | Ecological status | Chemical Status | Total evaluation |
| Elbe (East) | | | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Harbour | | | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Elbe (West) | | | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Elbe (transitional zone) | - | | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |

| | Compliance with target values unknown | ☺ | Compliance with target values probable | ☹ | Compliance with target values improbable |
|---|---|---|---|---|---|

Tab. I: Results of the monitoring (translated and modified from ARGE-Elbe, 2005)

## 2.2 Pressures

With regard to pressures that will negatively influence European and/or national Directives, the following challenges need to be differentiated:

### 2.2.1 Environmental risks

Environmental risks in Hamburg have been voiced with regard to the following issues:

a) Legacies of the past. In 2005, six historic contaminated sites with significant effects on the water quality in Hamburg and seven sites, which were strongly suspected to have significant effects, were identified (Freie und Hansestadt Hamburg, 2005). The main contribution due to old legacies seems to be introduced with water and sediment from upstream areas. In the A-report to the WFD, 17 groundwater bodies have been identified in the Elbe catchment, for which compliance with the WFD objectives is unclear or improbable due to old legacies: All of these are either in the Mulde-Elbe-Schwarze-Elster- (MES), Saale- (SAL), Middle Elbe-Eide- (MEL), or Havel- (HAV) coordination area. Extensive industrial production areas in former Czechoslovakia and the German Democratic Republic left large volumes of highly contaminated soils and sediments, which still pose a risk to downstream areas even though industrial emissions have been largely reduced (see Heise et al. 2005).

b) Current industrial emissions. Annex A1 of the "Commission Decision 2000/479/EC of 17 July 2000 on the implementation of a European Pollutant Emission Register (EPER) according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC)" states threshold levels for substances above which releases by industry to the environment have to be reported to the European Pollutant Emission Register (http://www.eper.cec.eu.int/eper/). In Hamburg Harbour, five industrial plants have reported to exceed emissions of those substances in direct releases to water (EPER – data from 2001). In the whole Elbe catchment, 179 industrial plants have been reported in 2005 to emit substances above the criteria given in the aforementioned Council Directive 96/61/EC or of priority substances for which limit values have been set in the daughter guideline 76/464/EEC (IKSE, 2005).

c) Oxygen depletion during summer months. After a recovery of the water quality of the river in the 1990s, the naturally occurring phenomenon of an oxygen decrease in the Hamburg region over the summer months has become more dramatic since 2000, resulting in the death of a large number of fish in some years. A number of hypotheses try to explain this trend that it may be caused by events such as the uninhibited plankton growth due to the reduction of inhibiting contaminants in the water, the increase of the dysphotic water body due to the continued deepening of the river, or the reduction of shallow water environments through active measures (ARGE-Elbe 2004).

d) Nutrient loads. Nutrient loads of the Elbe at Seemannshöft in Hamburg between 2000 and 2002 for total nitrogen were 126.000 t/a and for total phosphorus 5.633 t/a (median values). Both derived mainly from diffuse agricultural emissions from the whole Elbe catchment (Behrendt et al. 2002).

e) The disposal of dredged material into the North Sea. The disposal of potentially contaminated material in the North Sea in an area belonging to the Federal State "Schleswig-Holstein" has raised concern with regard to possible contamination of fish and impacts on the marine environment (Nix 2005; "Kontroverse um die Verlagerung von Baggergut" Die Welt, Artikel vom 11.03.2006)

f) Morphological changes such as diking and deepening of the river in the area of Hamburg led to an increase in the tidal range at the measurement pole in St. Pauli from 2.60 m in 1963 to 3.35 m in 1978 (WWF 2003). In 2004 the tidal range in Hamburg was 3,57 m. This development has led to a decrease in the freshwater tidal flood plains, which are exceptional biotopes home even to endemic plant species. Nature protection groups like the Bund fuer Umwelt und Naturschutz Deutschland (BUND) demand the integration of the remaining tidal floodplains into the "Flora and Fauna Habitat"-areas (FFH) (BUND Hamburg, 2004).

### 2.2.2 Economical aspects

a) In order to keep the Harbour functional, a minimal navigational depth must be maintained. For this reason, dredging activities are necessary. Depending on the degree of contamination, the dredged material is either treated (size classification and separation, dewatering)

and disposed of on land, or relocated to the Elbe. Restrictions with regard to time and environmental parameters are specified that need to be observed during dredging and relocation operations (Freie und Hansestadt Hamburg 2002):

- Relocation is only allowed during ebb tide in order to reduce sedimentation in shallow areas.
- Relocation is forbidden between April and August (fish breeding season).
- In September and October, special attention needs to be paid to the oxygen concentration that must not decrease below 6 mg/l.

The amount of material that needs to be dredged per year has risen dramatically. From approximately 2 to 3 m $m^3$/a until 1999, it has risen to almost 9 m $m^3$/a in 2004 (HPA 2005). This situation has become increasingly difficult, as the space for on land disposal of contaminated material is limited, treatment and disposal itself is expensive, and relocation of material during summer is not allowed. Additionally, simulation models showed that due to an effect called tidal pumping, approximately 80 % of the material that is relocated just downstream of Hamburg is transported back to the Harbour area (Glindemann, personal communication).

In search for a practical and economically feasible short-term solution, HPA and the Waterway and Shipping Directorate in charge (WSA Nord) developed a sediment management concept for the Tidal Elbe, advised by the Federal Institute of Hydrology and the Institute for Hydraulic Engineering. This concept envisaged a disposal of 4.5 m $m^3$ altogether of dredged material in the North Sea between 2005 and 2008 (Ministerium für Landwirtschaft, Umwelt und ländliche Räume 2005; HPA 2006). It is currently being investigated to what extent these plans collide with the OSPAR and London Conventions and the national "Guidelines for the Treatment of Dredged Material" (HABAB, BfG 2000).

b) On 12.09.2006 the official request for the next deepening of the Elbe was handed in by the Hamburg Port Authority (HPA) and the Waterway- and Shipping Office (WSA) Hamburg to the responsible authorities (Press release 12.9.2006, City of Hamburg). In order to stay competitive with other large harbours, the HPA plans a deepening of the Elbe River by 1m. This would allow container ships of the new generation with a capacity of 8000 TEU[1] and a depth of up to 14.5 m to enter the port (Ginzky 2005). Deepening of rivers can affect current velocity, tidal range and sediment transport. Beside other factors, the deepening of 1999 is being discussed in the media as a reason for the increase of sedimentation in the harbour area. The potentially increasing risk of storm surges with increased tidal ranges unsettles residents downstream of Hamburg. The City of Hamburg started a campaign in which a facilitator was instated to communicate the situation to the concerned public.

### 2.2.3 Social aspects

The attitude of the public towards the quality of the Elbe River can be assessed as positive and the official Elbe-Bathing Day on 17 July 2005 (Fig. 6) was regarded as a success. However, a number of nature protection groups warned that not all is well with the Elbe (e.g. Rettet-die-Elbe e.V., BUND, NABU). Awareness of contamination in sediments is low. However, the current disposal of material in the North Sea and the plans of the deepening of the Elbe raised a lot of concern and gained attention in the regional and national media[2]. Most public concern is centred around human health and safety risks, e.g. the increase of flood risks as a consequence of the river deepening, and employment.


Fig. 6: Elbe Bathing Day on 17 July 2005 (Image RiverNet).

Impacts on the Elbe fishery are another issue that is tackled by media and brought to public attention in connection with measures carried out in the Hamburg region of the Elbe. Only 4 to 5 fishermen still work on a full-time professional basis in this area and approximately 10 times more people on a sideline basis. The Elbe fishery is a very traditional profession and valued as part of Hamburg's history, as is the fish market – one of Hamburg's main attractions. The fishermen's observations with regard to the quality of the Elbe waters and the abundance of fish have a high credibility with the public. Reports in the newspapers about unusually large amounts of dead fish repeatedly caught since the year 2000, which coincided with the last deepening of the river and the removal of 10% of the freshwater wadden area "Mühlenberger Loch" in favour of a new airstrip of the Airbus company increased public concern about planned measures in the Hamburg region[3].

Promises of the Airbus industry to employ several thousand people in the process of building the new Airbus A380, however, resulted in controversial discussions and conflicts between those people that saw their jobs being threatened by environmentalists, and those people that wanted to prevent the extension of the airfield either because they wanted to keep the quality of the suburban area that was going to be sacrificed for the airstrip or because they wanted to save the nature protection area "Mühlenberger Loch" from destruction[4].

[1] TEU – Transport Equivalent Unit

[2] http://www.abendblatt.de/daten/2005/07/27/463615.html
http://www.welt.de/data/2005/07/28/751742.html
http://www.abendblatt.de/daten/2005/08/01/465262.html
http://www.abendblatt.de/daten/2005/08/13/470306.html

[3] „Tote Hose in den Netzen" – Hamburger Morgenpost, 07.06.2001

[4] http://www.abendblatt.de/daten/2004/10/26/356608.html
http://www.abendblatt.de/daten/2003/09/30/213601.html
http://www.abendblatt.de/daten/2003/03/01/129586.html

## 2.3 Impacts on the Environment

### 2.3.1 Chemical contamination

The quality of the water has improved a lot since the 1990s. A persisting problem, however, are contaminated sediments that can re-introduce dangerous or potentially dangerous substances into the water column if resuspended. Via bottom-dwelling organisms, contaminants may also enter the food chain by direct contact. In Fig. 8, average chemical data of sediment cores from annual samples of two stations between 2001 and 2004 are compared. For comparison an area directly upstream of Hamburg (Bullenhausen) and an area further downstream, in the western part of Hamburg (Parkhafen) (for locations see Fig. 7) were chosen. Depicted are chemical concentrations as percentage of the sediment target values according to the current ARGE-Elbe Classification (ARGE-Elbe 1996). The figure shows, that a) most heavy metals, some PCBs and TBT exceed the target values and that b) the contamination upstream of Hamburg is higher than in the Harbour area. The decrease is due to the diluting influence of relatively clean material that is transported into the region by the tides, but it also demonstrates the high impact of sources upstream of Hamburg.

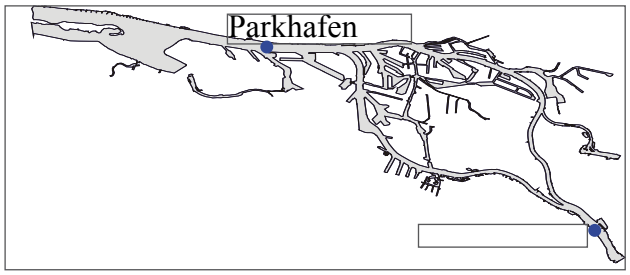


Fig. 7: Positions of compared sediment core analyses in the harbour

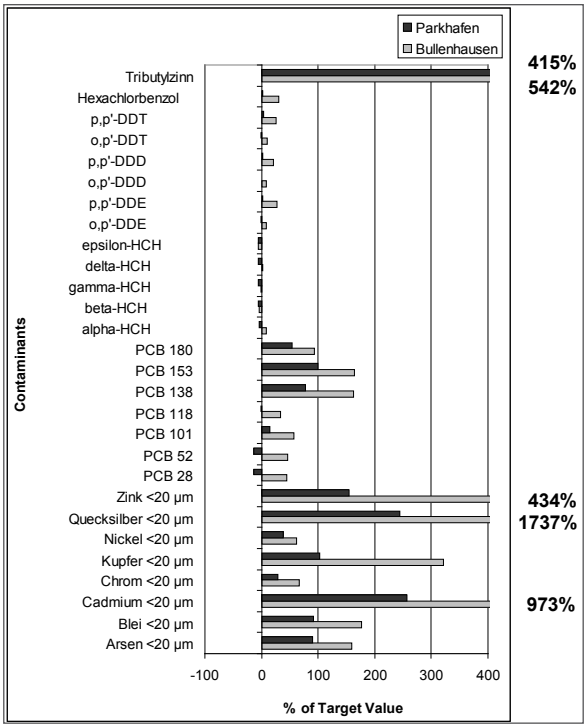


Fig. 8: Contaminants according to the ARGE-Elbe Classification, measured in sediment cores between 2001 and 2004. Data: HPA

A contaminant, whose emission in the Elbe River is mainly restricted to Hamburg, is tributyltin (TBT), which has been used extensively in antifouling paints for decades. TBT is a toxic substance with estrogenic effect and very low effective concentrations. Figure 9 shows the increase of TBT in sediments in the centre of the harbour area and especially near the "Reiherstieg", where traditional dock yards and small harbours are located.

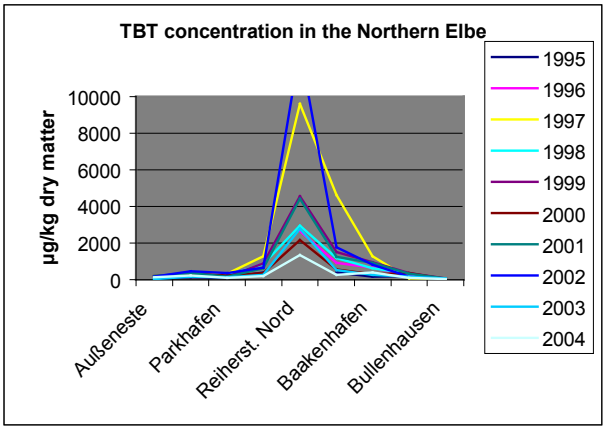


Fig. 9: TBT Concentration in the northern part of the Elbe River between 1995 and 2004. Data: HPA (Heise et al. 2005)

Concentrations have been decreasing since its ban by the IMO (International Maritime Organization, www.imo.org) in 2001. According to this "Antifouling Convention", application of TBT containing paints had to cease by 2003 and by January 1, 2008, a complete ban on the presence of organotins acting as biocides in antifouling paints should come into force. Even though the degradation rate of TBT in sediment is low, this substance will not continue to be an environmental problem. However, doubts have been voiced whether so called "booster biocides" that were recently introduced as alternatives to organotin compounds in antifouling products and which are mostly based on copper metal oxides and organic biocides (e.g. Irgarol 1051, diuron, Sea-nine 211, dichlofluanid) will not create a new environmental problem (Konstantinou & Albanis, 2004; "Science for Environment Policy" 2006).

### 2.3.2 Habitat preservation

There has been a lot of debate about the Flora Fauna Habitat (FFH) areas to be assigned in the Hamburg region. The European Commission criticised in the first proposal handed in by Hamburg for its FFH and EU-Bird protection areas that habitats in the estuary and for characteristic fish species such as Allosa fallax (germ. "Finte") and Lampreta fluviatilis (German „Neunaugen") were missing. Currently, Hamburg has assigned 14 FFH areas and 6 EU-Bird protection areas, which add up to 8 % of the Hamburg region. With regard to the critical points mentioned by the EU Hamburg argued that estuaries, defined as brackish water zones, commenced further downstream and outside of Hamburg borders. New FFH areas inside the harbour, as suggested by the EC for the protection of fish habitats, were seen unnecessary as the listed fish species were either not considered Elbe-specific or as protected by other FFH areas (press release Stadt Hamburg from 18 January 2005).

Whether the FFH areas that have been designated will eventually protect the rare tidal floodplain forests in Hamburg has been questioned by WWF and BUND. The rise in medium tidal high water due to the morphological modi-

fications of the Elbe river (see below) is not tolerated by the forest and a withdrawal to the hinterland is usually restricted by dikes (WWF 2003)[1].

### 2.3.3 Morphological changes

Currently, an environmental impact assessment for the planned deepening measure is carried out, with publication expected at the end of the year 2006. However, following the last deepening activity, a number of changes were observed and listed by the WWF (2005)[1]:

a) Increase of tidal range: Reduction of low water level at Bunthaus (upstream of Hamburg) by 5.7 to 8.5 cm, increase of upper water level at St. Pauli (in Hamburg) by 5 cm. This impact had been predicted by the authorities.

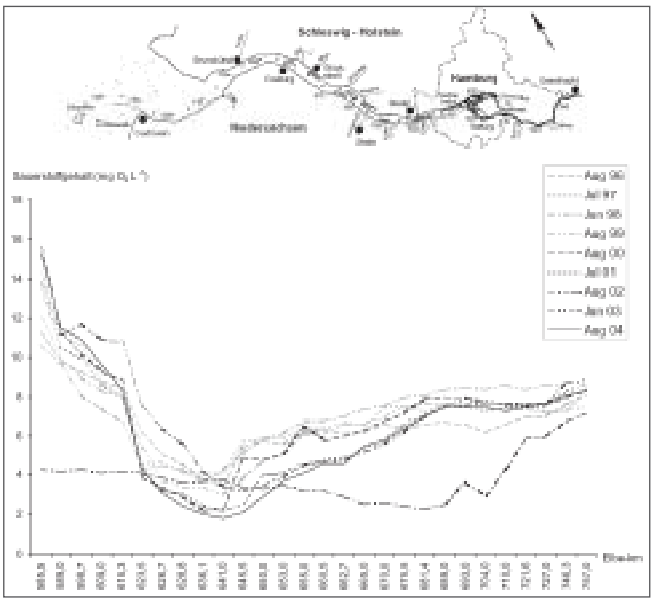

Fig. 10: Comparison of longitudinal profiles in the Tideelbe in the years 1996 to 2004 at times of extensive oxygen depletion. Data from ARGE-Elbe. (WWF, 2005, by Kerner & Jacobi)

b) Intensification of the oxygen depletion in Hamburg (predicted effect exceeded) Since 1999, a trend to lower minima and wider effected areas has been observed. The oxygen concentration below which fish are endangered is estimated to be 3 mg/l. In 2005, oxygen concentrations dropped below 2 mg/l in Seemannshöft (Fig. 11), resulting in a large number of dead fish (Hamburg Morgenpost, 6.7.2005). Reasons for the oxygen depletion may be manifold.

Fig. 11: Overview over dissolved oxygen concentrations in Bunthaus (BU) and Seemannshöft (SH) and Water temperature (SH:TW) over the last 6 months (Data and Graph: BSU Hamburg)

The ARGE-Elbe suggested next to the river deepening the removal of shallow water areas like side branches of the Elbe, harbour basins and the Mühlenberger Loch. Shallow areas serve as oxygen production areas, while large volumes of dysphotic water bodies that are increased by the deepening measures, shut off the phytoplankton from the light, preventing photosynthesis and initiating oxygen-demanding degradation processes (ARGE-Elbe, 2004). The influence of potentially increasing water temperatures of the Elbe river due to climate warming on oxygen concentration has not been quantified yet to the authors' knowledge but can not be excluded.

c) Increased sedimentation at shallow areas and in anabranches of the Elbe (predicted effect exceeded).

d) Increase of maintenance dredging in Hamburg (predicted effect exceeded)

e) Increase of the fine grain sediment fraction in the whole area of the Tideelbe (predicted effect exceeded)

f) Increase of net-transport of sediment towards Hamburg (not quantifiable).

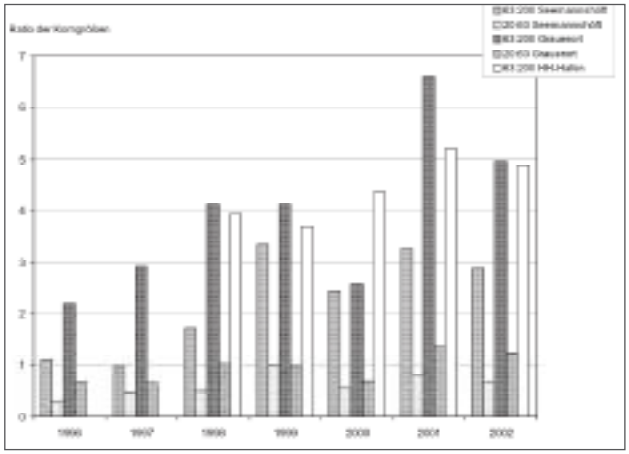

Fig. 12: Changes of ratios in grain sizes <20 to 20-63µm and <63 to 63-200 µm in suspended matter at three different locations in the Hamburg Area between 1996 and 2002 (WWF, 2005). Data: ARGE Elbe, Sedimentkataster

Fig. 12 depicts the increase of the grain size fraction <63 to 63-200 µm in the Hamburg area from 1996 to 2002. A higher content of fine material induces habitat changes and can have adverse impacts on fish and invertebrates. In addition, this is material that adsorbs contaminants and stays resuspended in the water column for a longer time. Therefore, impacts need to be analysed with respect to the water quality as well as to the diversity of organisms in these areas.

[1] http://fhh.hamburg.de/stadt/Aktuell/pressemeldungen/2005 januar/18/2005-01-18-bsu-hafen.html

## 2.3.4 Disposal of dredged material in the coastal area

The Hamburg Port Authority (HPA) sees a main cause for the increasing amounts of dredged material in the relocation of dredged material downstream of Hamburg. Due to a dominant upstream transport of sediment during flood tides ("Tidal pumping"), about 80 % of the material that is discharged in that area is transported back into the harbour. Hence, plans are currently being developed to break the build up of material by relocating it in the coastal area outside the effect of tidal pumping. Other possibilities including the building of an additional upland disposal site have been considered. For long term management, a concept for a sustainable development of the Tidal Elbe River is being discussed[1].

Chemical analysis of the material that is going to be relocated showed increased concentrations of HCH, DDT and chlorobenzenes (BfG 2005), which require a classification of the material into class 3 according to the national "Guidance on Handling of Dredged Material in Coastal Areas" (Handlungsanweisung für den Umgang mit Baggergut im Küstenbereich, BfG, 1999).

The preliminary evaluation of ecological effects and potential conflicts due to the relocation or disposal of this material to different areas is depicted in Table II. As can be concluded from this table, disposal at any of these locations will potentially lead to conflicts with the objectives of the Water Framework Directive, and all except Tonne 3 show potential conflicts with the Flora and Fauna Habitat Directive. It has been decided to use Tonne 3 as disposal site, but at this site also, medium impacts on oxygen content, nutrient concentrations, contaminant concentration, ecotoxicological effects and potential adverse effects on the existing fauna are to be expected (BfG 2005).

| Impacts | Tonne 3 54°01'N/07°58'E | Station Bake ca. 748 | LZ4b ca. km 733 | Wedel ca. km 638 |
|---|---|---|---|---|
| Change of Bottom sediments | ? | ? | | |
| Turbidity increase | | | | |
| Oxygen content | | | | |
| Nutrient concentrations | | | | |
| Contaminant concentrations | | | | |
| Ecotoxicological effects | | | | |
| Impacts on Fauna | ? | ? | ? | |
| Impact on Flora | ? | ? | ? | ? |
| Natura 2000 | | | | |
| EU-WFD | ** | ** | ** | ** |

| Adverse impact/conflict potential | low | medium | high |
|---|---|---|---|
| | Conflict potential, Flora and Fauna need to be evaluated | | |
| ** | Potentially large conflicts, exceptions possible | | |
| ? | Data evaluation not yet finished | | |

Tab. II: Preliminary evaluation of ecological impacts and conflict potentials through relocation and disposal of dredged material (from BfG, 2005, modified)

This classification does not necessarily forbid any relocation but requires the evaluation of other options giving due consideration to potential ecological and economical impacts. If class 3 material is relocated, volumes and contamination need to be reported to OSPAR[2] and LC[3]-Commission, and OSPAR needs to be informed about the reasons for this decision. Also, the ecotoxicological class of this material requires a case by case decision.

[1] Concept for a sustainable development of the Tidal Elbe River as an artery of the metropolitan region Hamburg and beyond. HPA 2006,http://www.hamburg-port-authority.de/images/stories/download/Strategiepapier_Tideelbe_komplett_english_final_ 051006.pdf

[2] Oslo-Paris Commission (for the protection of the North Sea and the North East Atlantic)

[3] London Convention - Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972

## 2.3.5 The Impact Matrix

The Impact matrix (Table III) summarises impacts specific to Hamburg in this part of the Elbe River due to various stressors on physico-chemical quality elements, biological quality elements, and hydro morphological elements.

The matrix was created on the basis of reports of the Department of Civil Engineering and Environment (BSU) in Hamburg on the implementation of the Water Framework Directive (Freie und Hansestadt Hamburg, 2005), on the C-report of the Elbe River Board/ARGE-Elbe for the tidal Elbe (ARGE-Elbe 2005), on Nehring & Leuchs (2000) and on the Neozoa-report by Gaumert (ARGE-Elbe 2000). The judgement on the extent of impacts portrayed in this article is mainly due to the authors' evaluation of above reports. Where the matrix claims that impacts are "suspected", this information is based on scientific research carried out by the ecotoxicological working group of Dr. Wolfgang Ahlf at the Technical University Hamburg Harburg. Ecotoxicological analyses of sediment and water from the Elbe River in Hamburg have shown significant inhibition of test organisms (worms, bacteria, algae) in various sampling surveys, covering the years 1994 to 2000 (e.g. Ahlf 1996; Ahlf et al. 2002). This inhibiting effect can, however, not be attributed to a specific diffuse or point source. Together with the low abundance observed in benthic macrofauna, a significant impact due to the mixture of different contaminants that reach Hamburg from upstream or are emitted in the vicinity is strongly suspected.

| | Impacts => | Physico-chemical quality elements | | | | | | | | | | | Biological quality elements | | | | | | Hydromorphological quality elements | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <= Pressure | | Transparency | Temperature | Oxygen conditions | Conductivity | Salnity | Nitrogen | Phosphorous | Suspended solids | Acidification | Priority substances | Other pollutants | Phytoplankton | Planktonic blooms | Macrophytes | Benthic invertebrates | Fishes | Pathogens | Hydrological regime | Morphology | River continuity | Tidal regime | Properties of river bed |
| Diffuse sources | Scattered settlements sewage | | | | | | | | | | | | | | | | | | | | | | |
| | Agriculture diffuse | | | | | | | | | | | | | | | | | | | | | | |
| | Forestry | | | | | | | | | | | | | | | | | | | | | | |
| | Urban storm waters | | | | | | | | | | | | | | | | | | | | | | |
| | Atmospheric deposition | | | | | | | | | | | | | | | | | | | | | | |
| | antifouling-emission from ships and dockyards | | | | | | | | | | | | | | | | | | | | | | |
| | upstream sources | | | | | | | | | | | | | | | | | | | | | | |
| | Relocation of dredged material | | | | | | | | | | | | | | | | | | | | | | |
| Point sources | Industrial wastewaters | | | | | | | | | | | | | | | | | | | | | | |
| | Municipial wastewaters | | | | | | | | | | | | | | | | | | | | | | |
| | Mining | | | | | | | | | | | | | | | | | | | | | | |
| | Contaminated lands | | | | | | | | | | | | | | | | | | | | | | |
| | Animal husbandry | | | | | | | | | | | | | | | | | | | | | | |
| | Solid waste management | | | | | | | | | | | | | | | | | | | | | | |
| | Aquaculture | | | | | | | | | | | | | | | | | | | | | | |
| | Peat production | | | | | | | | | | | | | | | | | | | | | | |
| Abstraction | Raw water supply | | | | | | | | | | | | | | | | | | | | | | |
| | Agriculture | | | | | | | | | | | | | | | | | | | | | | |
| | Industry | | | | | | | | | | | | | | | | | | | | | | |
| | Fish farming | | | | | | | | | | | | | | | | | | | | | | |
| | Hydropower | | | | | | | | | | | | | | | | | | | | | | |
| | Open cast coal mining | | | | | | | | | | | | | | | | | | | | | | |
| Morphological pressures | Dams (transversal) | | | | | | | | | | | | | | | | | | | | | | |
| | Weirs (transversal) | | | | | | | | | | | | | | | | | | | | | | |
| | Longitudinal embankments | | | | | | | | | | | | | | | | | | | | | | |
| | Straightening and widening | | | | | | | | | | | | | | | | | | | | | | |
| | Dredging | | | | | | | | | | | | | | | | | | | | | | |
| | Urbanisation | | | | | | | | | | | | | | | | | | | | | | |
| Hydrological pressures | Flow regulation (rivers) | | | | | | | | | | | | | | | | | | | | | | |
| | Hydropeaking | | | | | | | | | | | | | | | | | | | | | | |
| | Level regulation (lakes) | | | | | | | | | | | | | | | | | | | | | | |
| | Change in riverprofile | | | | | | | | | | | | | | | | | | | | | | |
| Other anthropogenic pressure | Recreation | | | | | | | | | | | | | | | | | | | | | | |
| | Fishing/angling | | | | | | | | | | | | | | | | | | | | | | |
| | Climate changes/increasing flood frequency | | | | | | | | | | | | | | | | | | | | | | |
| | Land drainage | | | | | | | | | | | | | | | | | | | | | | |
| | Overgrazing | | | | | | | | | | | | | | | | | | | | | | |
| | Introduced species | | | | | | | | | | | | | | | | | | | | | | |
| | Introduced diseases | | | | | | | | | | | | | | | | | | | | | | |

not significant for this case study
No effect
Low impact
Moderate impact
High impact
Suspected impact

Tab. III: Hamburg-specific impact matrix

# 3 The problems and their transnational dimensions

The environmental challenges that arise in the Hamburg area derive from a) its location downstream of a river basin with (historically) extensive industrial emissions; b) the activity of the port which demands extensive anthropogenic modifications of the Elbe in Hamburg and which partly clashes with the objectives of European environmental regulations; c) the impact of a large city with 1.7 m inhabitants and industrial production and its vicinity to the North Sea, which leads to the tide induced sediment transport upstream and relatively strict regulations regarding disposal of dredged material in that area.

a) Figure 13 depicts the distribution of contaminants in sediments above current threshold levels in the Elbe Basin. It clearly shows that – originating from a certain source – downstream areas are impacted by transport of contaminants and that major sources for contaminants are located upstream. Addressing these risks posed by contaminants when drawing up the Programme of Measures for the EC seems essential. Only by applying a river basin management approach can the sediment quality in Hamburg be improved.

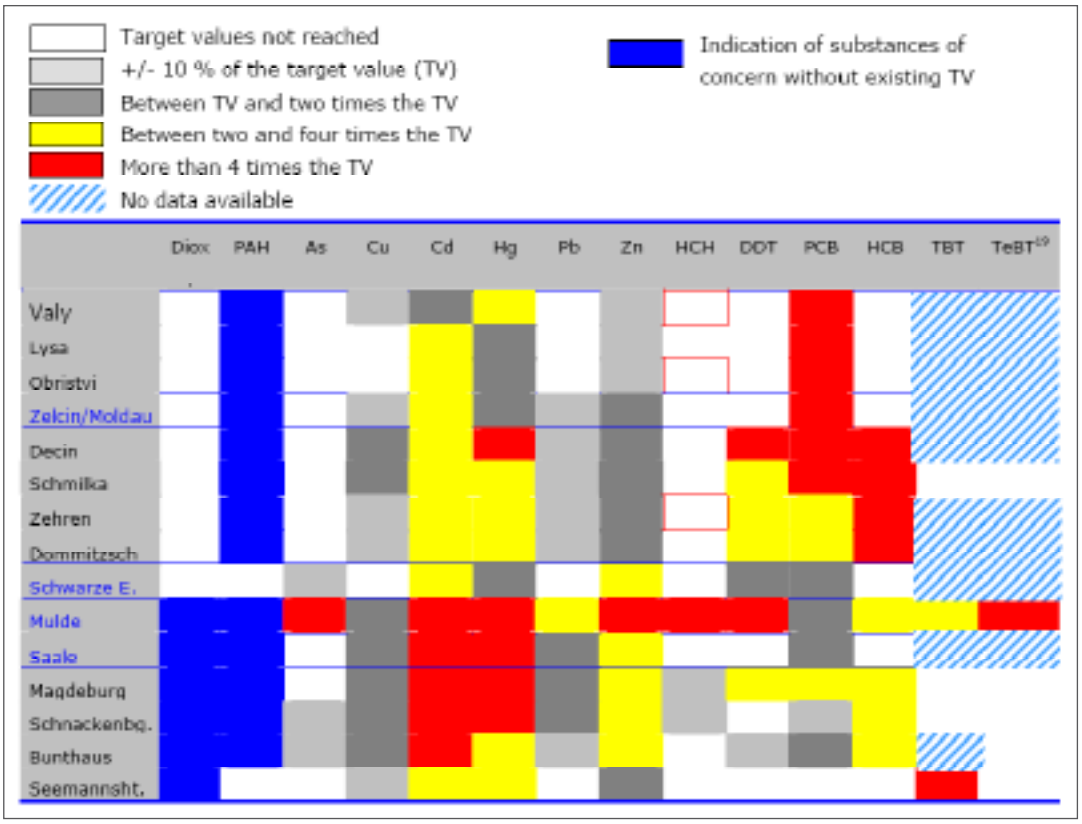


Fig. 13: Exceedances of target values for different „substances of concern" in different regions along the Elbe River (Heise et al. 2005)

b) Due to the morphological modifications that have been made so far, the harbour area has been tentatively classified as a "heavily modified water body". As has been shown in Table II, compliance with target values is unlikely, and neither the good chemical, nor the good ecological status will be achieved. Whether a good ecological potential as required for HMWB will be achievable, will need to be evaluated.

With regard to the Habitats Directive, the EC demanded that more sites of community importance needed to be identified in Germany, and it was proposed that the harbour waters in Hamburg were classified as FFH-region. In that case, a further deepening of the river would have been difficult as it would have been contradictory to the non-deterioration principle. Consequently, a political discussion including former German chancellor Gerhard Schröder resulted in the recommendation, that the harbour area would not be included in the Natura 2000 network. Nevertheless, on December 2005, the Commission sent Germany a final warning for not taking sufficient action to comply with a 2001 European Court judgement, which found that Germany had not submitted an exhaustive list of designated nature conservation sites under the EU Habitats Directive. If Germany fails to remedy this situation the Commission could take the case to court a second time and ask the court to impose a fine. Explicitly mentioned in this press report is the Elbe Estuary (Communiqué de Press from December 20, 2005, IP/05/1640).

c) The emissions of Hamburg itself being in the centre of a "catchment-coast continuum" (Salomons 2005) may also have an impact on the quality of the coastal zone, either from point sources such as communal waste waters and industrial effluents, or from diffuse sources such as run offs of storm water and from agricultural fields, as well as resuspension or relocation of sediment. This potentially affects not only the German coast but also Danish harbours and the Wadden Sea. Up to now, no quantitative assessment of the impact of diffuse sources on Elbe coastal waters has been carried out to the knowledge of the authors. Any future assessment would also need to address the effects of climate change.

## 4 Potential or implemented solutions

The diversity of interests in a region does not necessarily prevent achievement of environmental objectives. However, the predominance of economical interests as the highest weighted criterion may prevent sustainable management if it is in conflict with environmental and societal interests.

Minimisation of adverse consequences of former activities needs to be strived for. As in the case of Hamburg, the oxygen depletion becomes an increasing problem, which will also directly influence the WFD due to its effect on fish. Measures to reduce this impact could include a further reduction of nutrient input via waste water into the Elbe as well as improved maintenance through extending shallow water areas to enhance photosynthesis, delivering oxygen during the most sensitive summer months.

Solutions for dealing with contaminated sites outside its own responsibility have been practised in the 1990s by the Port Authority of Hamburg. Circumventing the Polluter Pays Principle, the port invested €150,000 in the construction of two settlement tanks for a Czech company that was known to be one of the primary emitters of mercury into the Elbe (Netzband & Reincke 2002). Consequently, the mercury load being emitting from this factory was reduced from 1.7 to 0.8 tons per year, cutting the total load of the river in 1995 by half (Fig. 14)

Currently, another concept for management of the tidal Elbe is in discussion seeking to combine engineering measures in the estuary, such as artificial islands, restoration of flood plains, and narrowing of the river mouth. It is anticipated that these measures will result in cushioning the tidal range, reduction of the flood-dominated sediment transport upstream into the river, lowering the storm surge peaks, and restoring biotopes. Long term, a concept like this, which has been developed by the Hamburg Port Authority in cooperation with the Waterway and Shipping Administration, will result in a reduction of dredging and sediment relocation activities as the current transport of sediment into harbour basins would be reduced.

The management concept will need to be environmentally compatible and socially acceptable while not compromising the economic function of the area.

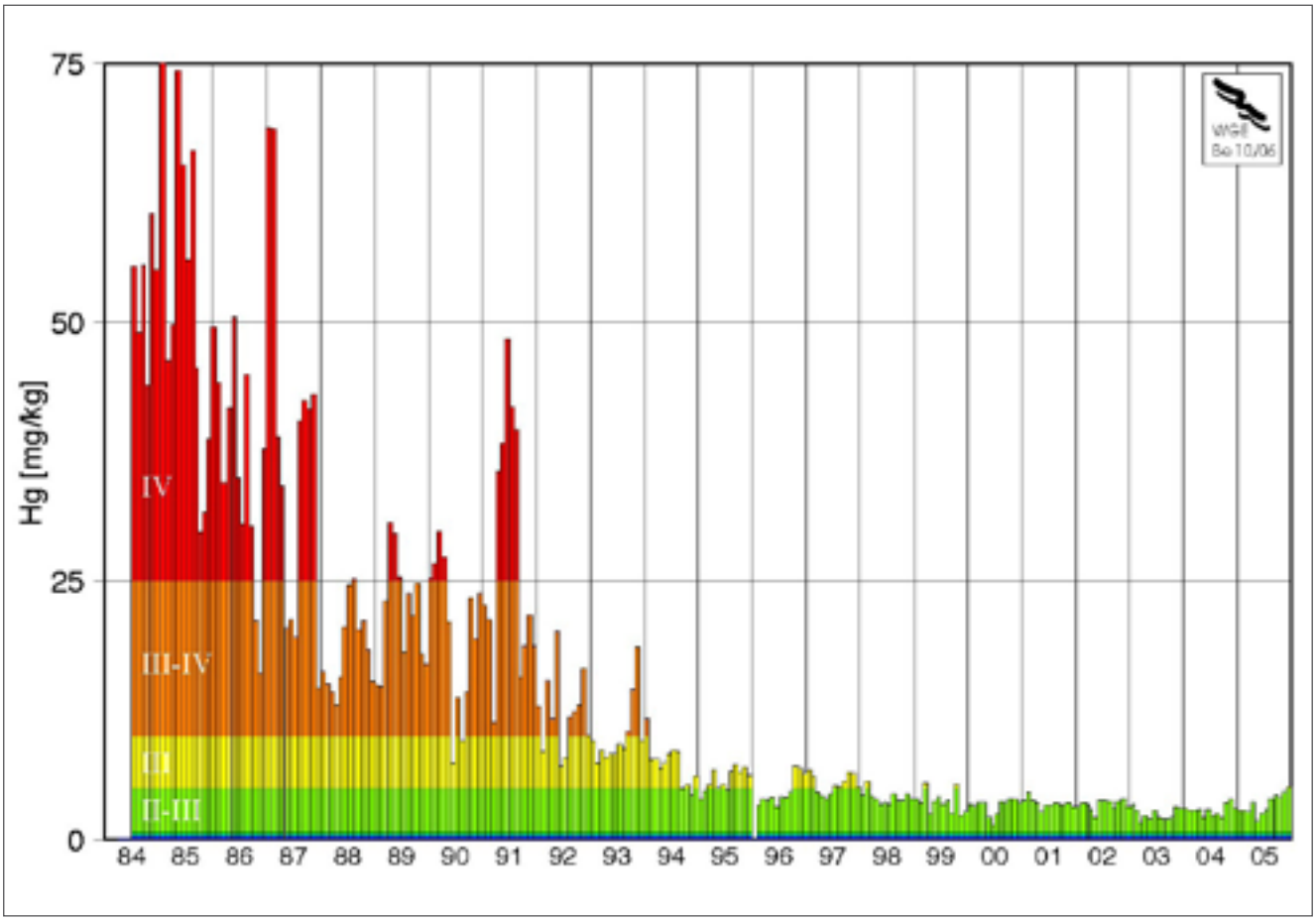


Fig. 14: Mercury concentrations in fresh sediments in Schnackenburg, former German-German border. Roman numbers are quality classes (rising contamination from I to IV) (Image: Wassergüteestelle Elbe)

# 5 Experiences gained and contributions made to sustainable river basin management

Experiences gained from the case study in Hamburg comprise the need for river basin planning. Hamburg is a good example of how site-specific problems can be caused by impacts upstream, which also can only be solved there, and how on the other hand, the catchment-coast continuum needs to be addressed as the specific site is interacting with areas downstream.

Hence, in cases when transregional or transnational problems along river basins occur, these can only be managed via a river basin approach. As an important early step in river basin management, a site prioritisation along a river basin has been suggested in order to allocate scarce financial resources where they can reach maximum effects (Apitz & White, 2003, Förstner et al 2004, Heise et al 2004). An example here is the cooperation between the Port of Hamburg and a company in the Czech Republic, where money was invested upstream outside the direct port's responsibility with a sustainable success for the whole German Elbe region.

# 6 Conclusions

The solution to existing or expected conflicts between different stakeholder groups, e.g. the sediment managers, environmentalists and citizens, who perceive a risk for their health or for their employment, can only be solved by long-term planning, communication and trust building. However, in urgent cases, such as the "sudden" and unexpected increase of sediment in the harbour which currently threatens its existence, developing a sustainable solution with participation of all stakeholders may not be suitable as this is a time-consuming process. If developments like this can not be predicted, short term solutions are needed, which may provoke conflicts with existing environmental laws. The disposal of contaminated dredged material in the North Sea is in conflict with the non-deterioration principle. The planned deepening measure of the Elbe may endanger compliance with the objectives of the Water Framework Directive and the Habitats Directive if effects of oxygen consumption become pronounced due to a shift of material towards finer grain sizes and loss of shallow water areas.

In order to manage this area sustainably, new concepts will have to be developed allowing to maintain the economic integrity but also reducing impacts on the environment. An approach to change the Elbe estuary morphologically, combined with a decrease of diking and creation of flood plains in order to modify sediment dynamics and tidal pumping effects, has been proposed by the Hamburg Port Authority. The concept envisions a reduction of incoming sediment volume while providing new habitats. If this concept is paralleled by measures in the upstream stretches of the river to improve the quality of the material that travels downstream, this may turn out to be a promising approach for a sustainable management of the Elbe River estuary.

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