Strategy Concept Elbe

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Abstract. The pollution of the Elbe River and especially the catchment area of the tributary Mulde with rising groundwater-level in the mining areas and tailings of the old mining in the Ore Mountains ist one of the great environmental problems of this catchment. In 1998 the strategy concept was installed to improve the Elbe water quality, reducing the impacts of uranium mining on the Elbe River. One main focus in the strategy concept was set on the use of passive water treatment methods: use of reactive materials and wetlands.

Introduction

The Elbe River is one of the major rivers in the western Europe. From its spring in the Giant Mountains (Czech Republic) to its mouth at the North Sea near Cuxhaven (Germany) it covers a distance of 1091 kilometres and a catchment area of 148 268 km^2 - one third of it located in the Czech Republic and two thirds in the Federal Republic of Germany (figure 1). Along its way the catchment drains some of north and central Europe's major cities including Prague, Dresden, Berlin and Hamburg.

The Elbe River arises in the Giant Mountains and flows through the Bohemia Chalk Basin, the Mid-Bohemia Highlands and the Elbe Sandstone Mountains before it reaches the middle course downstream the Castle Hirschstein (between the cities Meißen and Risa), the Middle and North German Lowland. Downstream from the city of Lauenburg there is the lower course of the river Elbe, comprises the stretch from the weir at Geesthacht to Cuxhaven and further on the North Sea. This is the tidal part, that means, that the flow is controlled by the tide (see figure 1). The water quality in the catchment area of the Elbe River has highly improved in the last twelve years (ARGE ELBE, 2000).

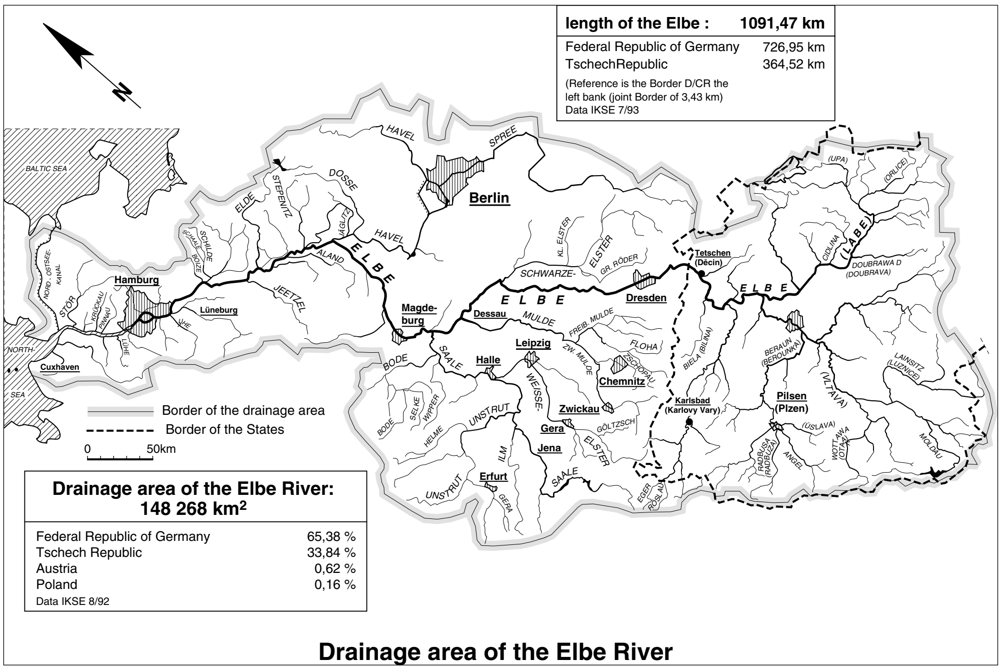


Fig. 1: Drainage area of the Elbe river.

239 great municipal treatment plants were built since 1990, with a capacity of 25,5 million inhabitant equivalents. You can find 61 in the Czech Republic, 177 in Germany and 1 plant in Austria. All communities with more than 20 000 inhabitants in the catchment area of the Elbe River have modern treatment plants now. Technology variations in the industrial and chemical plants and a better handling of the industrial wastewater the share pollutants from industrial areas has decreased.

More success have been watched concerning the number of fish-species comparing the time of german reanification and now. Now we have 94 fish-species in the whole catchment area, 36 of it in the czech area. Salmons are expected in the tributaries of the River Elbe of "Swiss Bohemia" as soon as possible. Never the less there are some "sorrows of tomorrow", which have to be solved in the next years, to get a good ecological condition of the tributaries in the old catchment area of Elbe River according to the European Water Framework Directive (2000/60/EG). The pollution of the river Elbe and especially the catchment area of the tributary Mulde with rising groundwater-level in the mining areas and tailings of the old mining in the Ore Mountains ist one of the great sorrows.

In July 1998 the conference of the Elbe River responsible ministers decided to develop a strategy concept to improve the Elbe water quality, reducing the impacts of uranium mining on the Elbe River. Beyond the existing research on geochemical engineering methods to treat water with increased concentrations of heavy metals from ore mining has to be pointed out. Strategies to avoid or to increase heavy metal concentrations in the Elbe catchment area have to be developed and possibilities to finance research have to be found.

Feasibility studies of Passive Water Treatment Methods

The effective fixation of heavy metals on the surface above the watertable is not simple to realise. For very big and diffuse emissions of reservoirs with often more than 10–100 years residence time, especially from mining (mine-buildings, surface mining, deposites, tailings) costly technical solutions are not tenable of economical reasons. In many cases there must be realised a combination of monitoring, based on a fixing of the sources (isolation of the contaminant species, pH-rising, multi barrier system) and a handling afterwards in similar-to-nature systems (wetlands).

With respect to the costs of mining remediation passive water treatment systems are the only possible methods for a longterm treatment of waters from mine sites. The passive treatment methods should be applicable with a minimum of energy, manpower and without the need of permanent renewal of chemicals. For the treatment of surface waters internationally mainly constructed wetlands are in practice. For the treatment of groundwater contamination there are only a few sites supplied with reactive permeable walls consisting of zero valent iron. Experiences from hydrogeochemical and biogeochemical research and from conventional water treatment methods are not much tested yet and there are still not sufficient investigations to optimise existing methods (Hurst, 2001).

One of the most important aspects of uranium mining remediation is the long-term durability of remediation methods. In this context the development of mine and seepage water quality is of special interest. As another item of research the combination of biological and chemical methods is of interest. In the strategy concept Elbe the focus was set on three topics concerning passive water treatment methods:

- constructed wetlands
- reactive materials for in situ mine water treatment
- infiltration and injection methods

In the following the concept will be introduced in details and will be reported about the update for preparing project sketch and the following realisation of a concrete project for application reactive covering systems and geotechnical handling concepts of the old mining sites. First research results are already presented.

It will be expected that the presented research topics will be realised with the support of the Federal Ministry of Research and the countries of Germany, especially the countries Saxony and Thuringia to realise the demands of a good ecological condition according to EC Water Framework Directive also in the catchment areas with old mining (metallogenic catchment type, Schneider et. al. 2002).

Feasibility study project: Reactive Covering Systems

The long-term mitigation of pore waters of acid waste rock dumps formed during uranium mining requires new remediation approaches. A pilot study was performed to evaluate the feasibility of reactive covering systems (RCS) as part of an alternative mineral covering system for uranium mining dumps (Schneider et al 2002). This kind of technology is a combination of geotechnical and geochemical methods. Some of the effluent waters of the rock dumps are characterized by pH values as low as 3 due to residues of acid from ore processing and pyrite oxidation.

Due to the high costs of classical pump-and-treat technologies, reactive barriers have been used increasingly in the last decade as an alternative strategy for remediation of water (U.S. Dept of Energy 1996). Reactive barriers are zones of high geochemical reactivity, where contaminants are immobilized in-situ by redox processes, co-precipitation, adsorption or biological processes. Usually they are classified as naturally formed or man-made (artificial) geochemical barriers. The development of reactive barrier systems for removal of radionuclides and heavy metals from percolating waters requires an improved understanding of the elementary processes that control the interactions between dissolved contaminants and barrier material (Schneider et al 2002). The reactive covering system was concipated especially or metal contaminated dumps. The high permeability of the dumped material provides the migration paths for the distribution of the reactive solution.

Principles of a reactive covering system

A special type of a reactive barrier is the reactive covering system (RCS), where a layer of the reactive material is located under the mineral soil of an alternative covering system. The reactive surface barrier will only be activated if there is a hydraulic breakdown of the mineral soil cover (Schneider et al 2002). When the covering system has lost its functionality, precipitation will percolate through the mineral soil cover and chemical reactions with the barrier will be initiated (see figure 2). After leaching, the dissolved reactive substances will be transported into the dump material and react there with the contaminated pore waters. The aim of this study is to evaluate the feasibility of several reactive materials with suitable chemical properties for efficient mitigation of uranium and radium-226 in an acid milieu. The results of the study should be applicable to many other uranium dumps with similar geochemical characteristics (Schneider et al 2002).

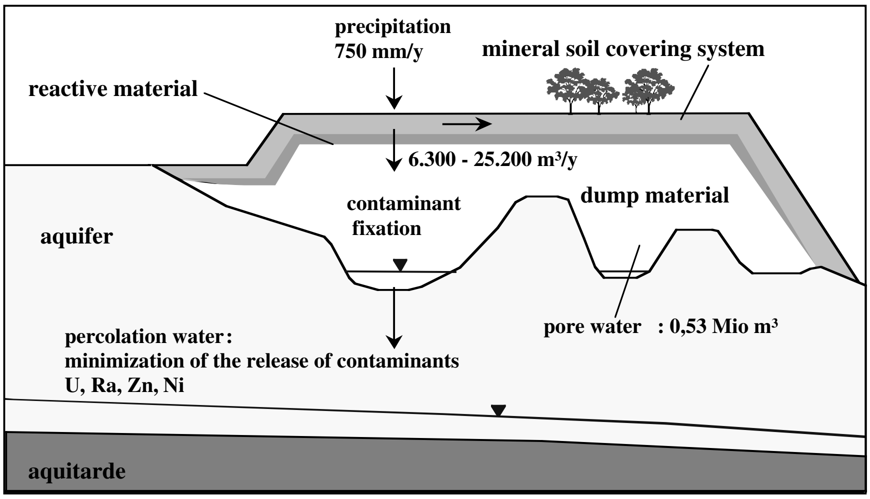


Fig. 2. Schematic cross section of a reactive covering system (Schneider et al 2002). The infiltration rate assumes the hydraulic breakdown of the soil cover.

Suitable reactive materials

One topic of the investigation is to evaluate suitable reactive materials for the mitigation of radionuclides and heavy metals in an acid milieu. In a theoretical pilot study PHREEQC geochemical modeling were included equilibrium and mixing calculations to evaluate the chemical interactions between dump waters and reactive materials (Schneider et al 2002). The engineering feasibility of RCS was evaluated calculating a mass balance considering different dump water hydraulics, layer thickness and pore water concentrations. The feasibility of using several RCS-suitable reactive materials for the mitigation of radionuclides and heavy metals was evaluated for the acid mine dump Schüsselgrund (Saxony, Germany) on theoretical scale. The main data on hydrogeology, hydrology and geochemistry of the Schüsselgrund site are given in Schneider et al. 1999 and Schneider et al. 2001. The main contaminants of the pore waters are uranium (20-30 mg/l) and radium-226 (about 1 Bq/l). In addition, contaminants such as zinc (50-150 mg/l), nickel (2-4 mg/l), and sulphate (2-4 g/l) are present in the pore water.

The main findings are that a RSB of zero-valence iron (Fe^0) causes a long-term mitigation of uranium and zinc. Alkaline hydroxides ($Ca(OH)_2$, $Ba(OH)_2$) cause the mitigation of radium-226. In the case of nickel, mitigation by Fe^0 and $Ca(OH)_2$ only occurred when the dump water constituted less than 30 % of the mixing solution. Fe^0 may be the most suitable reactive material to mitigate uranium and zinc in an acid milieu. The changes in geochemical milieu by oxidation of Fe^0 cause a mitigation of uranium. In addition to redox changes, uranium-sorptive iron hydroxides will be formed after transformation of Fe^0 to Fe^{2+}. According to its chemical properties (dissolution rate), a lifetime of 2150-8500 years has been calculated for the reactive barrier (Schneider et al 2002).

Alkaline hydroxides have been identified to be the only suitable reactive material for the mitigation of radium-226. In contrast to Fe^0 and alkaline hydroxides, PO_4-compounds have no redox-effective properties. The reactivity of these materials is characterized by the formation of insoluble uranium-phosphate-complexes. The feasibility of PO_4-compounds as a RCS for uranium mitigation was not definitively determined. The theoretical study strongly suggests that the use of RSB can provide a sustainable mitigation concept for radionuclides and heavy metals in an acid milieu (Schneider et al 2002).

Taking into consideration the prognostic character of the theoretical modeling of the pilot study, the next step will be lab and field measurements. Based on the results of this feasibility study, laboratory experiments have been initiated. According to the different reactivities of the investigated barrier materials, a mixture of different reactive materials has to be considered as a combined mitigation concept. Our experiments will investigate if mixed reactive materials remain reactive for the mitigation of radionuclides and heavy metals when barrier material interactions are taken into account (Schneider et al 2002).

Feasibility study project: Injection Methods

Another type of geotechnical methods for the mitigation of uranium mining sites are injection methods. This kind of mitigation concept will be investigated for contaminated uranium sites with a very low permeability, e.g. tailings. The technological principles of this remediation concept base on the minimisation of the permeability of the contaminated source. In special drillings reaching the contaminated source will be injected clay minerals to decrease the pore volume of the tailings. The technical conception and optimisation is topic of this feasibility study project. Otherwise it will be tested to combine injection methods and reactive materials in order to inject reactive solutions to cause an in-situ mitigation of contaminants.

Conclusions

In Saxony, the draining water from nearly all of the uranium mining sites flow into the Mulde River, which is a tributary to the Elbe River. The aim of the Saxonian regulatory authorities is to minimise the radionuclide concentrations in the Mulde, its sediments, and its meadowlands. Therefore, an alternative treatment method must be developed in the catchment area of the Mulde, at least until the mines have been flushed 6 to 8 times (Hurst 2002). If the mine water or seepage water is needed as drinking water, or if the runoff flows into a fishing area, measures have to be found to remove the radium and, sometimes also the arsenic, out of the water. However, conventional methods of doing this have high long-term costs and produces wastes that have to be disposed of. Passive treatment methods are being assessed. For passive water treatment to be effective, the hydrogeochemical system and the water chemistry have to be known very well. The potential benefits of natural attenuation processes also have to be considered. The use of passive water treatment methods will minimise the catchment management costs especially due to the demands of the EC Water Framework Directive.

References

ARGE ELBE (2000) Die Wassergüte der Elbe im Jahr 2000, published by Wassergütestelle Elbe.

Hurst S, Staupe J, Leder F (1998) German regulations referring to long-term surveillance and maintenance stewardship – in theory and in practice, U.S.DOE: Long-Term Stewardship Workshop, June 2-3, 1998

Hurst, S.; Schneider, P.: (2001) Improvement of longterm effectiveness of passive water treatment systems, Proceedings on Side meeting at ICEM`01 on „Natural Attenuation in Uranium Mine and Mill Remediation“ Thursday, October 4, 2001 Brügge, Belgium

Hurst S (2002) Remediating 700 years of Mining in Saxony: A Heritage from Ore Mining. J Mine Water and the Environment, Special Issue: Large Scale Modeling of the Environment 21: 3 - 6.

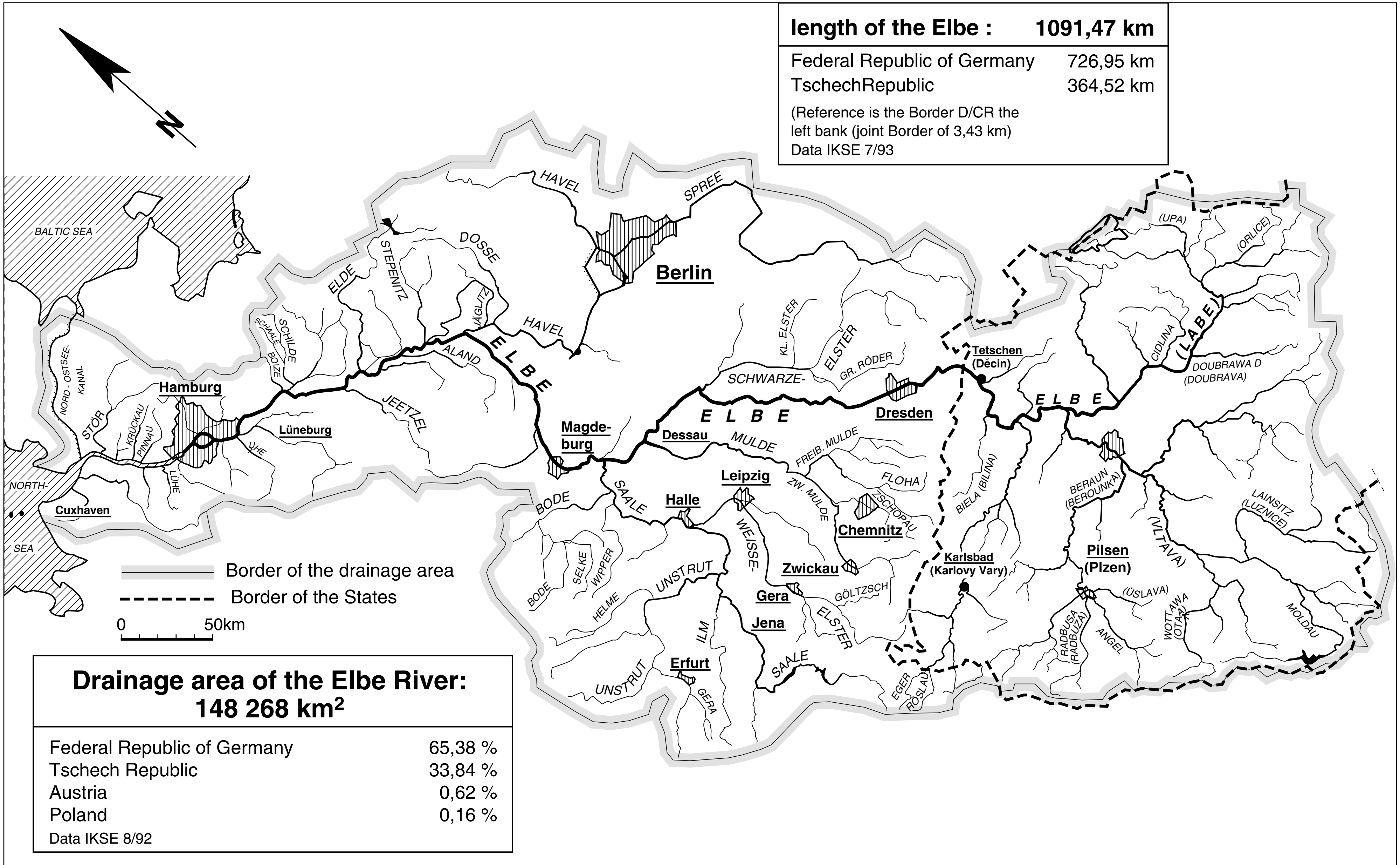
Schneider P, Voerkelius S, Nindel K, Forster M, Schreyer J (2001a) Release of Contaminants from Uranium Mine Waste - Laboratory and Field Experiments. In: Mine Water and the Environment. Journal of the International Mine Water Association (20): 30 -38.

Schneider P, Neitzel PL, Schaffrath M, Schlumprecht H (2002): Leitbildorientierte physikalisch-chemische Gewässerbewertung - Referenzbedingungen und Qualitätsziele. in: Abschlussbericht zum F&E-Vorhaben des Umweltbundesamtes (FKZ 200 24 226), Chemnitz, 2002, 149 S.

Schneider P, Neitzel PL, Osenbrück K, Noubactep C, Merkel B, Hurst S (2001b) In-situ Treatment of Radioactive Mine Water Using Reactive Materials - Results of Laboratory and Field Experiments in Uranium Ore Mines in Germany. Acta Hydrochim. Hydrobiol. 29: 129 - 136

Schneider P, Osenbrück K, Neitzel PL, Nindel K (2002) In-situ mitigation of effluents from acid waste rock dumps using reactive barriers - A feasibility study, J Mine Water and the Environment, Special Issue: Large Scale Modeling of the Environment 21: 36 - 44.

U.S. Dept of Energy (1996) Research and application of permeable reactive barriers, DOE-K0002000 (Subcontract No. DE-AC 13-96DJ87335)



length of the Elbe : 1091,47 km

Federal Republic of Germany	726,95 km
TschechRepublic	364,52 km

(Reference is the Border D/CR the
left bank (joint Border of 3,43 km)
Data IKSE 7/93

Drainage area of the Elbe River:
148 268 km^2

Federal Republic of Germany	65,38 %
Tschech Republic	33,84 %
Austria	0,62 %
Poland	0,16 %

Data IKSE 8/92

Drainage area of the Elbe River