Physico-chemical surface water conditions of catchments with metallogenic origin: A contribution to the establishment of the EC Water Framework Directive 2000/60/EG in Germany

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Abstract: For the realisation of the EC Framework Water Directive in Germany, the reference conditions of metals in surface waters have to be determined taking into consideration the so called surface water landscape. In catchments of metallogenic origin metals and radionuclides like uranium influence the quality of the surface waters. In this study, the quality status of metallogenic (Ore Mountains, Harz, Rhine Slate Mountains) and other surface water landscapes were compared in order to differentiate factors influencing the natural background in similar geological formations.

Introduction

In the year 2000 the EC Water Framework Directive (2000/60/EG) passed the parliament of the European Community (EC), which then became legal law in all countries of the EC. The main objective of the EC-directive is to achieve a good quality of all surface, ground-, estuary and coastal waters. This includes an assessment of the chemical status of the surface waters (environmental quality standards for nearly 30 priority compounds and substances) and a five-stage ecological classification of waters. According to the regulations three groups of characteristics are important for the European surface waters, namely: hydrobiology (priority), hydromorphology (supporting hydrobiology) and physico-chemical conditions (supporting hydrobiology). “High water quality” (class I) hence reflects natural conditions totally, while class II refers to “good water quality”. Additionally the maximum ecological potential is taken as reference for heavily modified and artificial water bodies (Irmer 2000).

Within an investigation project, financed by the Environmental Federal Agency (UBA) of Germany, all available analytical data of low polluted or close to natural surface waters in 30 different water landscapes of Germany were collected and analysed by statistical methods (Schneider et al. 2002, Neitzel et al. 2002). The data base included summary and effect indices, major ions, salts and nutrients, heavy metals (Cd, Cr, Ni, Hg, Pb, U, Zn), as well as As and Cu. The aim of the study was the elaboration of a physico-chemical data base for the assessment of the natural background of surface water bodies in Germany (Neitzel et al. 2002). This data base was used to define the reference status according to their hydromorphological and geological setting. Regarding the quality of surface waters, the EC Framework Water Directive requires the level 'good ecological and chemical quality' to be reached in the year 2016. In this study, the quality status of metallogenic (Ore Mountains, Harz, Rhine Slate Mountains) and other surface water landscapes was compared in order to differentiate factors influencing the natural background in similar geological formations.

Physico-chemical surface water assessment of catchments with metallogenic origin

Assessment of physico-chemical data of surface waters

In order to meet the requirements of the EC Framework Water Directive in Germany, reference concentrations (= natural background concentrations (Fergusson 1990)) of metals have to be determined taking into consideration the so called surface water landscape. In catchments of metallogenic origin, heavy metals and radionuclides like uranium can influence the quality of the surface waters. As investigations showed, the following geological formations were of metallogenic origin: granite, slate, gneiss, diabase, and Grauwacke. The data were compared to reference concentrations of metals and uranium in surface waters with low anthropogenic influence.

Data pool

LAWA (Länderarbeitsgemeinschaft Wasser/German Water Association) defined the reference status as natural background concentrations of a non-anthropogenic influenced catchments in 1998. The investigated data base of 560 measuring locations of 30 different surface water body types contains 3.500 analytical data sets. All data were analysed using statistical methods. Mean, 10-, 50-, and 90-percentils as well as minimum and maximum values were calculated. The representative data base obtained the assessment of the sustainability of the environmental quality standards as defined by LAWA.

Surface water landscapes with metallogenic origin

Part of this study was the investigation of the quality status of metallogenic surface water landscapes. As the results of the physico-chemical data assessment show, the Ore Mountains, the Harz Mountains and the Rhine Slate Mountains differ significantly in their metal content from the other catchment types. Hence the metallogenic surface water landscapes have to be given a special status.

Results

Main results of the investigation of all surface water landscapes

Physico-chemical data of 30 different types of surface water landscapes were investigated according to the surface water landscape classification of Briem (2001). The results of the statistical analysis show, that the surface water bodies in Germany can be summarised in six catchment types (Fig. 1):

- bogs and bog riverside meadows
- salinic catchment type
- carbonatic-dolomitic catchment type
- sandy-clayey catchment type
- silicatic catchment type and
- metallogenic catchment type

Heavy metals bound to particular matter (based on 50 percentils)

For all catchment types, with the exception of the metallogenic landscapes, the reference status of lead, chromium and mercury met the quality standards of class I (high water quality standard) of LAWA, while cadmium, copper, nickel and zinc values were found to be increased in all catchment types. A reference status for these parameters cannot be defined in the particular matter of metallogenic landscapes with the exception of mercury.

Heavy metals in the total liquid phase (based on 50 percentils)

A reference status referring to high water quality standard (class I) was evaluated for following heavy metals:

- chromium: all catchment types
- copper and lead: carbonatic-dolomitic catchment type
- nickel: all types excluding sandy-clayey catchment type and salinic type
- zinc: carbonatic-dolomitic type, silicatic type, sandy-clayey catchment type

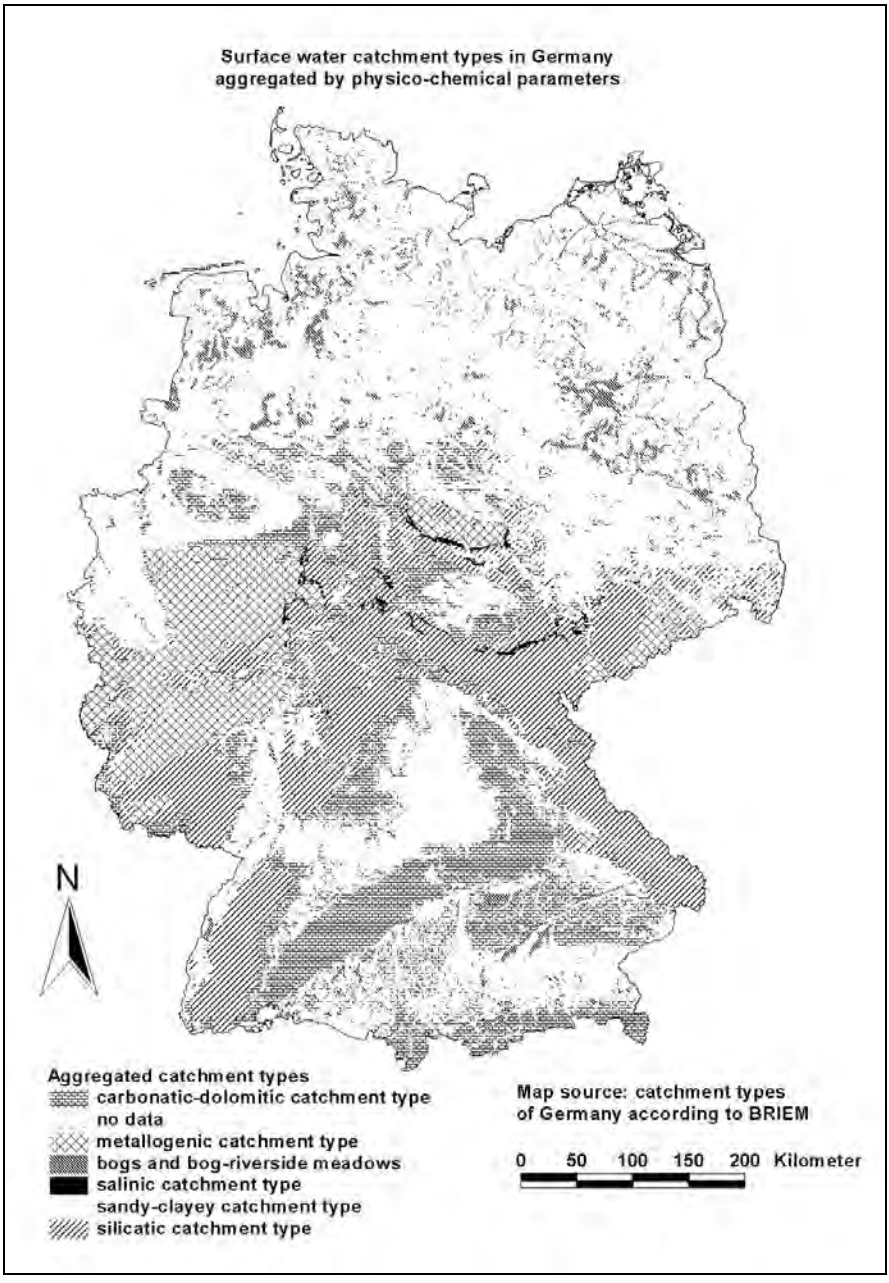

Fig. 1. Aggregated surface water landscapes according to the results of the physico-chemical assessment.

No reference status was found in whole Germany for cadmium and mercury considering NOEC-standards (No Observed Effect Concentration) with respect to the most sensitive water organism. There are different causes for this situation: various diffuse and historical pools as atmospheric deposition, use of fertilizers and solution effects of acid rain in the soils.

Metals/metalloides in the liquid phase (based on 50 percentils and means)

No LAWA quality aims exist for aluminium, arsenic, barium, iron, cobalt, manganese and uranium. The results of the statistical analysis provide a data base that can be used do define a reference status for these parameters. These results also correspond to data found in literature.

Main results of the investigation of the metallogenic catchment types

The results of the investigation of the metallogenic catchment types in comparison to the quality class I (the natural background) of LAWA (1998) and the other surface water catchment types are summarized in the tables 1 and 2.

Table 1. Metals in the suspended phase - comparison to the quality class I of LAWA (1998) (based on 50 percentiles)

metal (mg/kg)	quality aim class I (LAWA)	bogs and bog river-side meadows	carbonatic-dolomitic type	silicatic catchment type	sandy-clayey type	salinic type	**metallogenic type**
lead	≤ 25	18	22	30	24	26	**175**
cadmium	≤ 0,3	1,0	0,4	0,5	0,3	1,0	**17,5**
copper	≤ 20	7,0	39	37	21	9,0	**81**
nickel	≤ 30	11	56	47	29	22	**120**
mercury	≤ 0,2	no data	0,1	0,2	0,1	no data	**0,2**
zinc	≤ 100	36	127	140	92	62	**1100**

Table 2. Metals in the liquid phase - comparison to the natural background of LAWA (1998) (based on 50 percentiles)

metal	natural background LAWA	bogs and bog river-side meadows	carbonatic-dolomitic type	silicatic catchment type	sandy-clayey type	salinic type	**metallogenic type**
lead (µg/L)	0,4 - 1,7	1,0	1,4	1,0	0,9	1,0	**2,1**
cadmium (ng/L)	9 - 36	250	100	150	130	150	**339**
chromium (µg/L)	1,3 - 5	0,5	0,5	0,5	0,6	0,9	**2,5**
copper (µg/L)	0,5 - 2	4,8	1,4	1,3	0,9	4,0	**2,4**
nickel (µg/L)	0,6 – 2,2	2,0	1,3	1,8	2,0	4,7	**5,6**
mercury (ng/L)	5 - 20	50	100	500	50	20	**188**
zinc (µg/L)	1,8 - 7	10	5,0	13	5,0	12	**28**

An increased metal status in the liquid phase in comparison to the natural background concentrations of the other surface water landscapes has to be considered for:

- Ore Mountains: cadmium, copper, zinc, lead,
- Harz Mountains: nickel, zinc,
- Rhine Slate Mountains: nickel, zinc, lead, copper.

The most increased metal status of all investigated geological metal rich formations (granite, slate, gneiss, diabase, Grauwacke) was found in slate. To evaluate the reference status of surface waters of mixing catchment types and catchments with anthropogenic influence a runoff-concentration-analysis was calculated using the Hellmann-method. There was no usable result due to the variability and occurrence probability of the catchment influences.

Conclusions

The results of the physico-chemical surface water assessment study provide the reference status of the metallogenic catchment types as base for the implementation of the EC Water Framework Directive in Germany. The results of the investigation of the reference status of surface waters show, that a special physico-chemical surface water status for catchments with metallogenic origin has to be considered. All reference data of metallogenic catchments where measured in areas with no mining activities. There is no suitable way to use the high LAWA quality aims for the implementation of the EC Water Framework Directive in metallogenic catchments. Especially the natural occurring metals cadmium, nickel, copper, zinc and lead cause a high potential of metals in the liquid and the suspended phase of the rivers draining metallogenic catchments.

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