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title: # A web map service of groundwater background values in Germany

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INTRODUCTION

One of the main objectives of the EU Water Framework Directive (WFD 2000) is to achieve a good chemical status of groundwater bodies. This requires the member states to determine the status of groundwater bodies and to define parameter specific threshold values that allow the identification of groundwater bodies at risk of failing to achieve good groundwater chemical status. Therefore intensive efforts were taken in Europe to identify suitable methods for the derivation of natural background levels and groundwater threshold values (Hinsby et al., 2008). As the natural composition of groundwater is mainly related to the rock type of aquifers, the geological surveys of Germany consequently started a joint project aimed at determining background levels of groundwater related to geology. The statistical analysis was based on hydrogeochemical rock units, derived from the Hydrogeological Map of Germany 1:200.000 (SGD 2009). A large number of naturally occurring major and trace elements were examined. The outcome is a nationwide map of the background levels of groundwater in Germany.

METHODS

The physical and chemical properties of groundwater are mainly determined by the composition of the seepage water, its alterations during passage through the unsaturated zone, the lithology of the aquifer and travel time of the groundwater. The natural geogenic properties of groundwater result from a dynamic equilibrium of groundwater and the rock surface, where complex chemical, physical and biological processes take place. Ancient groundwater in greater depth is mainly influenced geogenically, while younger and shallow waters tend to show more influences from the surface including anthropogenic indicators. In such groundwater pure geogenic properties often cannot be found anymore and in many cases the background values show a more or less prominent anthropogenic influence.

For the study presented here groundwater analyses from about 48,000 sampling points distributed over all of Germany measured between 1980 and 2005 were collected in a database. Samples with a known anthropogenic point influence such as from landfills were discarded from the dataset. As basis map the digitally available Hydrogeological Survey Map of Germany 1:200,000 (http://www.bgr.de/Service/grundwasser/huek200), which contains more than 1100 hydrogeological units, was aggregated into a map of nearly 200 hydro-geochemical units (HGU). The outcrops of this map represent the geology of the upper aquifer. A HGU represents a hydrogeological unit with a characteristic distribution of background values in its groundwater. Those distributions can be described statistically e.g. by box-whisker-plots. The statistical analysis was performed using probability plots, separating the anomalies of a data set from the underlying normal population. The 90th-percentiles of this population are defined as the parameter specific groundwater background values. The procedure is described in detail by Walter et al. (2010).

SPECIFICATIONS OF THE WEB MAP SERVICE

The results of the data analysis are available as a web map service (WMS) via the internet. At present the language is German but an English extension is in planning.

The WMS can be accessed via an internet address (URL with or without parameters):

http://www.bgr.de/Service/grundwasser/huek200/hgc_p90/

http://www.bgr.de/Service/grundwasser/huek200/hgc_p90/?REQUEST=GetCapabilities&VERSION=1.1.1&SERVICE=WMS

With this technology the background values of the units can be shown in maps and info queries can be launched. For visualisation WMS-capable programs like Google Earth, ESRI ArcGIS or an internet map-browser are necessary. At http://geoviewer.bgr.de/ the WMS has already been integrated and can be viewed.

The WMS contains 85 different data layers. A total of 40 parameters as listed in table 1 are shown in the WMS. Only naturally occurring inorganic parameters were taken into account, including relevant trace elements.

Table 1. Groundwater parameters shown in the web map service.

Major elements		**Trace elements**		**Physico-chemical parameters**
sodium (Na)	aluminium (Al)	strontium (Sr)	zinc (Zn)	total hardness
potassium (K)	ammonium (NH_4)	silver (Ag)	arsenic (As)	spec. electrical
calcium (Ca)	boron (B)	bismuth (Bi)	cadmium (Cd)	conductivity
magnesium (Mg)	barium (Ba)	cobalt (Co)	chrome (Cr)	pH-value
chloride (Cl)	bromine (Br)	copper (Cu)	mercury (Hg)	
sulfate (SO_4)	fluoride (F)	lithium (Li)	molybdenum (Mo)	
hydrogen carbonate (HCO_3)	iron (Fe)	nickel (Ni)	lead (Pb)	
	manganese (Mn)	antimony (Sb)	selenium (Se)	
	phosphate (PO_4)	tin (Sn)	thallium (Tl)	
	silicate (SIO_2)	uranium (U)	vanadium (V)	

For each parameter two layers are being provided: the parameter specific maps show the hydro-geochemical units in colours, shaded in 5 classes depending on the specific background values. The background values are represented by the 90th-percentiles of the statistical evaluation of the measurements within the areal extent of the respective HGU. Fig. 1 shows the map of background values of hydrogen carbonate for Germany. The northern part of Germany, which is depicted in a grey colour, is still in progress, because in this area the hydrogeological units showed distinct spatial variations of the hydro-geochemical properties. Therefore the HGUs cannot be determined by an aggregation of units but instead a subdivision of the units is necessary. Full coverage of Germany is expected until 2011. However, available point data are being provided for this area in the WMS.

After choosing a parameter of interest from the list, the WMS provides an overview map of Germany with the distribution of background values for this parameter. Zooming in is possible through the functionality of the browser.

Upon clicking on the polygon of a HGU an info menu is being activated and the window shown in figure 2 opens, presenting numerical values of the statistical data. The position of the HGU chosen is highlighted in an inserted map (Fig. 2, right bottom) in yellow. The following data are provided: name and size of the HGU and statistical parameters (percentiles) of the distribution of the geogenic basic population of the parameter in the respective unit. The percentiles are being illustrated by a box-whisker-plot (Fig. 2 right top).

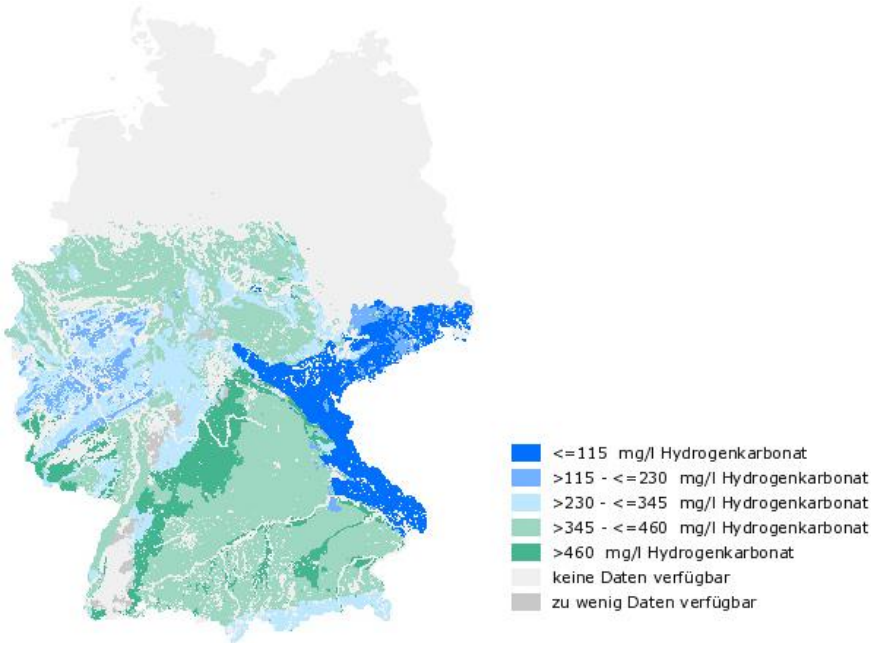
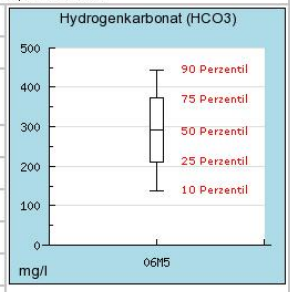
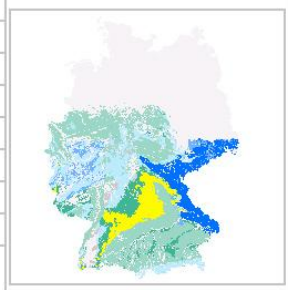


Figure 1. Map of the background values of groundwater in Germany for the parameter hydrogen carbonate.

Abfrageergebnis: HÜK200, Hydrogeochemie des oberen Grundwasserleiters, 90 Perzentil	
Hydrogeochemische Einheit (Name)	mittlerer und oberer Keuper, klastisch
Hydrogeochemische Einheit (ID)	06M5
Flächengröße	13273 km²
Parameter	Hydrogenkarbonat (HCO3)
95 Perzentil	488. mg/l
90 Perzentil	**444. mg/l**
75 Perzentil	372. mg/l
50 Perzentil	291. mg/l
25 Perzentil	210. mg/l
10 Perzentil	138. mg/l
5 Perzentil	94. mg/l
Messwerte - nachgewiesen	680
Messwerte - kleiner Nachweisgrenze	0
Messwerte - ausserhalb Normalverteilung	0
Anteil ausgeschlossener Messwerte	0 %
Richtwert nach WHO (2004)	
Grenzwert nach TrinkwV (2001)	
Geringfügigkeitsschwellenwert (LAWA, 2004)	





ausgewählte Einheit Legende

Figure 2. Result of an info query of a hydro-geochemical unit (depicted in yellow) for the parameter hydrogen carbonate, obtained upon clicking on a polygon of the unit.

Besides the spatial illustration of the background values, the measuring points used for the statistical evaluation are also shown in the WMS. In analogy to the polygons, the point data are coloured in 5 classes depending on the measured values of the parameters. Point data are depicted in circles, when they represent the HGU shown in the polygon where they are located, and in triangles, when they belong to a different HGU i.e. in most cases an underlying deeper HGU. An example is shown in figure 3. Again an info query is possible by clicking on one of the measuring points, which yields further information (name of allocated HGU, measured value of chosen parameter, filter depth). Depicting the point data enables the user to crosscheck local situations of measured parameter values and thus to relate the statistical data determined for the HGU to the actual situation in an area.

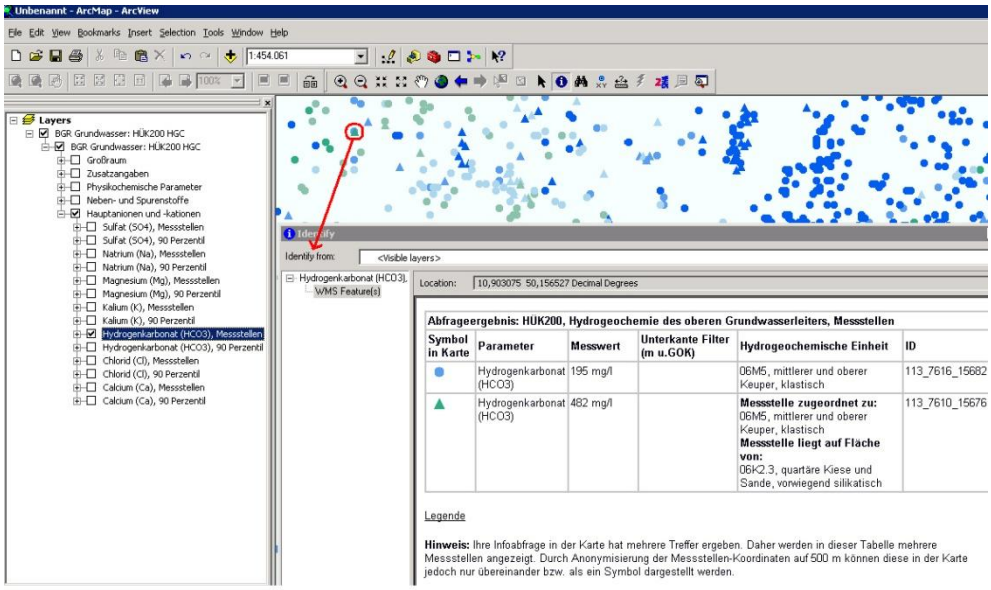


Figure 3. Detail of the point layer (top) and result of an info query of point data for the parameter hydrogen carbonate (bottom). The detailed information is obtained upon clicking on the point symbols.

Due to requirements of data protection laws, the point data are made anonymous by disguising the exact position of the points within a radius of 500 m and by hiding the object names. Thus the points shown in the map cannot be related to the real objects.

RESULTS AND CONCLUSIONS

Compared to previous studies, the statistical evaluation of groundwater quality in Germany presented here is the most detailed approach so far. However, this investigation has to be regarded as a macro-scale approach, giving an overview at a nationwide scale.

The maps of parameter-specific background values of the different hydro-geochemical units are an ideal basis to answer many questions related to groundwater quality. They can be used as a tool to evaluate groundwater analyses in their regional context. Through the knowledge of typical regional distributions of parameter values, exceedances of threshold values can be in-

vestigated and local geogenic or anthropogenic anomalies can be identified. Additionally, the data can be used for the evaluation of the qualitative status of groundwater bodies as required by the EU Water Framework Directive. The direct access to the data via internet offers great comfort for the users.

There are still gaps, especially concerning trace elements, which have not been measured systematically by all water authorities in Germany. Due to the requirements of the Water Framework Directive in some federal states trace element measurement programs of groundwater have been launched in the meantime. Therefore in the foreseeable future it will be possible to further extend the contents of the presented WMS.

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