WIDESPREAD GEOGENIC SALT WATER OCCURENCE IN NORTH GERMANY - DEMONSTRATED ON THE BASIS OF A GENERALIZED MAP -

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Abstract

Geogenic NaCl-salinization is a severe problem in the public water supply of North Germany, because increasing areas in the utilized aquifers are involved. This paper describes the occurence of widespread salinization in the pore water aquifers of Miocene and Quaternary age in North Germany. According to a new overwiew map altogether around 25 % of North German aquifers show inland salinization (upconing deeper salt waters and salt diapir dilution), about 5 % sea water intrusion. The relevance of geogenic salinization for public water supply can be recognized by nearly 100 water works that are affected by salinization more recently. Of these 16 had to be shut down mainly because of influence of geogenic salt water.

1 Introduction

Geogenic NaCl-salinization is a problem in the public water supply of North Germany, because increasing areas are involved. The problem is mainly concerned with inland salinization, while sea water intrusion is of minor importance. As a result of former wise development of water extraction plants geogenic salinizations are of less importance than antropogenic induced nitrate-, pestizid-, and sulfate enrichments. Still salinization pose a latent danger to the long term use of ground water resources in North Germany, a problem which was neglected in previous scientific investigations and development strategies.

Still too little is known about the overall extend of geogenic salinization. To achieve a picture of the future development in this field intensive studies are needed. The following information were compiled during a scientific project at the DVGW-Research Institute of the Technical University of Hamburg-Harburg* (DVGW = German Waterworks Association). The task was to compile a state of the art report on the salinization in its view of the scientific principals,

the knowledge of its distribution and the impact on public water works in North Germany as well as the technical methods to avoid future damage (GRUBE, WICHMANN, HAHN & NACHTIGALL 2000).

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2 Characteristics and distribution of salinization

In North Germany ground waters with a concentration of less than 1 g TDS / l generally are called fresh waters, waters with a higher concentration are called salt waters. From a practical point of view areal occurences of cloride contents of a scale of 30-50 mg TDS / l can be seen as indicators for geogenic salinizations because anthropogenic concentrations are generally less than that. Sulfatic salinizations are also found in North Germany but have a minor distribution only. Impairs of the public water supply by salinization are due to the bad taste (espec. chloride), corrosion (espec. sulfate) as well as hampering of purification treatment (chloride). Additionally aesthetic aspects with coloured humic substances occur in ground waters in the vicinity of salinizations.

Geogenic ground water salinizations in North Germany are mainly due to salt water intrusion, upconing deeper salt waters and salt diapir dilution. Upconing deeper salt waters and salt diapir dilution can generally be summarized as inland salinization. Futher sources of salinization play only a minor role. Principally the long term dilution of aquifers might so have an influence. At the coast the input of salt in shallow aquifers by aerosols or spray water and the flooding of fresh water aquifers during storm flood, can increase salt concentration. Small scaled higher salt concentrations in aquifers can also be the result of increased evaporation at the coast and in low inland areas.

Principally the salinization by river infiltration belongs to the group of geogenic salinizations. In North Germany these reach a larger importance because of anthropogenic substances and water extraction. Anthopogenic salt waters are very manifold. Generally a differentiation of anthropogenically induced (e.g. road salts, fertilizers, old waste deposal sites) *and* anthropogenecally influenced salinizations (e.g. as a result of gw-extraction, dewatering) can be differentiated. The focus of this study was on geogenic salinizations.

The occurence of salinization mainly depends on the regional hydrogeologic and hydraulic situation. Generally salinization in this study means the geogenic salinization of the North German Plains with its porewater aquifers utilized for drinking water purposes. The aquifer systems in North Germany with its mainly younger tertiary and quaternary deposits show a heterogeneous structure. The salinization therefore shows different distributions and the salt concentrations are very variable. Complete salinizations occur as well as local salinizations or salinizations near the basis of aquifers. Principally deeper aquifers are more affected than the shallow aquifers, in which a permanent exchange of water by meteoric waters takes place. High concentrations of many ten thousend mg TDS / l can be observed in both deep and shallow aquifers. Ground water salinizations are not restricted to old „stagnating" waters, because comparibly young ground waters are affected by salt diapir dilution. Generally the large scaled hydraulic patterns in the inland areas lead to a more difficult and larger scaled picture than that of sea water intrusion at the coast (see fig. 1).

Figure 1: Hydrogeological-hydrodynamic model of the North German Basin with possible large scaled salt water movement (ZIESCHANG 1974)

3 Knowledge on salinization in North Germany

In the following it will only be refered to small scaled overview studies. There are numerous detailed studies of the single german states or regions within these (see GRUBE et al. 2000). A number of overwiew maps of salinization for North Germany has been compiled in the past. The areas shown in these maps partly differ from one another as a result of use of different interface definitions and different models used, e.g. different attitudes towards the size of upconing effects. The information content of these maps especially differ between the former western and eastern part of Germany. While in the east an areal investigation exists there are less information in the western part. Early maps of the northwestern part have been compiled by MARTINI (1951), GRAHMANN (1958), AURAND et al. (1980), VIERHUFF et al. (1981) and RICHTER (KELLER red. 1979). In the Northeastern part of Germany early overview maps have been prepared in the sixties in the scale of 1:200.000. The ZGI (1974) prepared a newer hydrochemical map in the same scale. In this map the interface was already shown (m above sea level). An overview map in 1:500.000 of the distribution of chloride salinization was published by the ZGI (1971). Important was the step to look on larger hydrologic systems. A combined map between Poland and the former German Democratic Republic was established in the 70ies (ZGI 1977, ZIESCHANG 1977).

More recent maps of salinization were prepared in the Northeastern part in the directive hydrogeological map 1:50.000. This map contained different issues (e.g. hydrogeology, endangering of ground water resources). The salinization was shown in relation to the single aquifers, which makes this map the most detailed that exists until now. The maps further shows the depths of the interface and saltspots respectively salinization in shallow aquifers. A synthesis of these detailed maps have been prepared on a 2-dimensional basis by REINSCH et al. (1990) in the scale of 1:500.000. In this map additional information on ground water salinization from other fields, e.g. investigations on mineral resources, have been included. An actual map in the scale 1:1.000.000 that covers the whole of North Germany was published by the BGR (MÜLLER 1993). The areas with inland geogenic salinization in this map are relatively small, while the sea water intrusion is shown comparibly widespread.

Actual map of the German Waterworks Association (DVGW)

Fig. 2 shows a small scaled version of a new map that combines the existing maps and other information on salinization in soft rocks of the North German Plains. In this map (original scale around 1:600.000; compatible to ARC-VIEW format) information of AMT FÜR WASSERWIRTSCHAFT (1984), GRUBE et al. (1996), HAHN (1991) and REINSCH et al. (1990) as well as own investigation results based on salinization principles. The map shows the areal extend of salinization in the utilized aquifers. Altogether around 25 % of North Germany show inland salinizations in utilized aquifers, about 5 % sea water intrusion.

The southern limit of the map is formed by the geological boundary between the thick pore aquifers at the rim of the hilly mountain countries to the south. This artifical limit shows a generalized boundary between pore aquifers and hard rocks. North of this limit only small scaled hard rocks occur in the vicinity of salt diapirs. The map includes verified and assumed salinizations. Assumed salinizations are included where no monitoring wells exist or only minor salt concentrations have been stated because of only shallow monitoring wells, but where the hydraulic situation likely led to salinization in the lower parts of the aquifer. This is true for exfiltration areas, e.g. the upper part of the Weser/Aller river. Other examples are the large geological basins and throughs, e.g. the troughs of Pinneberg and Kaltenkirchen in Schleswig-Holstein.

Hydrogeological information is included in the form of the distribution limit of the Rupelclay (REINSCH et al. 1990), areas with a reduced thickness or generally missing of Rupelclay (REINSCH et al. 1990, for the state Brandenburg: SCHIRRMEISTER 1997) and the salt diapirs (JARITZ 1972, BALDSCHUHN et al. 1999, REINSCH et al. 1990) that occur close to the surface (less than 400 m) and that have a proven or assumed influence on ground water (dissolution).

Of course a main factor for the occurence of salinization is the hydraulical situation. The map shows ground water potentials of the uppermost utilized aquifer. For graphical reasons Fig. 2 contains partly older information on the basis of publications from HECK (1949), HAHN (1991) and recent unpublished data from WASY GmbH (Berlin) for the eastern parts. This information corresponds with actual maps of the BGR that have been prepared as a provisional survey (see original map in GRUBE et al. 2000).

The map can be used for a demonstration of global coherences of the main geological and hydraulical factors and geogenic salinization. With the exception of Schleswig-Holstein salinization generally does not occur in areas where these potentials reach more than + 50 m NN. Salinizations occur mainly in areas with low ground water potentials, especially in the large valleys (Elbe, Weser, Aller) and other low lying areas acting as exfiltration areas. These areas with salinization are mainly elongated in its extend. Widespread areal salinization can be recognized in the geological troughs and synclinal structures between of alongside the salt diapirs where a smaller exchange of ground water respectively smaller ground water velocities occur. A major factor in Northeast Germany is the extend of the Rupelclay, that normally seperates the fresh water from the salt water beneath the clay. In the area of the distribution limit where this hydraulic barrier ends and a massive upward movement of saltwater in the higher lying utilized aquifers can be observed. The same is true for the areas in which the Rupelclay was eroded by the glaciers and glacial meltwaters (buried valleys). The distribution limits of aquitards are also of importance in the southern area and are here due to upward directed ground water potentials from older strata, e.g. of the Jurassic. A direct subrosion of salt diapirs and a resulting salinization can only be shown in some cases. Generally a differentiation between subrosion waters and upconing deeper salt waters is difficult. Obviously not all diapirs close to the surface have an influence on ground water chemistry. This can be explained by aquitards on top of the diapirs. In other areas a proof of salinization is still lacking.

Table 1: Overview of the extend of proposed and assumed salinization in North Germany

State	State area [km^2]	Sea water intrusion [km^2]	percentage [%]	Inland salinization [km^2]	percentage %]
Brandenburg & Berlin	29.280	-	-	8.500	29,0
Hamburg	754	-	-	340	44,8
Mecklenburg-Vorpommern	23.570	155	0,7	5.230	22,2
Niedersachsen und Bremen	37.70	3.15	8,4	7.330	19,4
Sachsen-Anhalt	8.480	-	-	2.180	25,7
Schleswig-Holstein	15.720	1.928	12,3	4.740	30,1
Sum	**115.536**	**5.239**	**4,5**	**28.318**	**24,5**

Nearly 100 water works in North Germany are classified as influenced by geogenic salinization (Fig. 2). Of these 16 had to be abandoned mainly because of salinization problems - besides other reasons like obsolete water work techniques etc. Since the reunification in 1990 problems with salinization mainly in the Northeast of Germany generally have decreased, at least outside the main metropolitan areas. This is the result of both decreasing industrial activity and water saving strategies. Nevertheless problems are still important e.g. in the areas of large towns like Hamburg, Potsdam and Lübeck.

Water works (Ww) influenced by salinization were mentioned if they show one or more of the following phenomena:

(i) Ww had to be abandend mainly because of high salt concentrations

(ii) Ww / wells had to be displaced to other places

(iii) Ww had to give up wells or fill parts of filters with sand or concrete to avoid pumping from salinized parts of an aquifer

(iv) Ww have to stick to certain extraction rates to avoid salinization

(v) Ww has to use horizontal filters to avoid salinization

4 Conclusion

It has to be noted that the salinization is underrepresented in actual statistical evaluations on a regional scale because for financial reasons only a few wells used for these interpretations

reach the deeper salinized parts of the aquifers and salinized areas are only infrequently investigated. A validated overwiew on salinization is therefore still missing.

There is a number of recent investigations on geogenic salinizations in different parts of North Germany, e.g. by the DVGW in Hamburg and Lübeck and in Brandenburg by the LGRB. Further Intensive investigations are carried out in the Gorleben area (see KLINGE et al. in this volume). In these paleohydrogeological moments are of importance (see KÖSTERS et al. in this volume). The tasks of the disposal of radioactive waste also led to the development of new modelling techniques (see SCHNEIDER in this volume). Detailed geophysical and hydrogeological investigations are carried out by NLFB / BGR between Cuxhaven and Bremerhaven (buried valley of Bremerhavener). Fresh water lenses are investigated on the island of Norderney.

These investigations will add to our knowledge on geogenic salinization in North Germany. The current map cannot be a substitution for planning maps or detailed surveys. In general in view of the vertical extension of geogenic salinization supplementary information would be desirable, but information is scarce at least in northwest Germany. Additional information might be sampled for the new Hydrogeological Map of Germany 1:200.000 that will be established under supervision of BGR / NLFB during the next 3 years. Future work will help to develop GIS based maps on geogenic salinization.

Figure 3: Distribution of geogenic NaCl-salinization and water works influenced by geogenic salinization in North Germany according to a compilation of the DVGW (2/2000).

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abbreviations used:

BGR - Federal Bureau of Geosciences and Resources, Hannover

LGRB - Geological Survey of Brandenburg, Kleinmachnow

NLfB – Lower Saxony Geological Survey, Hannover

ZGI – former Central Geological Institute of the GDR, Berlin