Ground Water Salinization in Northern Germany - New Developments in Research -

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Abstract

Northern Germany shows different forms of geogenic groundwater salinization of which the intrusion of sea water, dilution from salt diapirs and upconing of deeper ground waters from different geological units (possibly Permian to Tertiary) are the most prominent. These salinized waters are a permanent potential threat for the extraction of fresh groundwater and a large number of waterworks is faced with the presence and especially the upconing of salinized ground water; some smaller catchment areas even had to be shut down. A regional scientific working group covering the North German Lowlands has been formed, in which the Geological Surveys, the Watermanagement authorities, Water Supply authorities and universities and private scientists are involved. The work of the group is focused on geogenic and anthropogenically influenced salinizations in soft rock aquifers of Tertiary and Quaternary age. Emphasis is put on the problems of longterm sustainable public water supply. The research areas and the working scope of the group are presented.

Introduction

The hydrological and hydrogeological conditions in Northern Germany (Fig. 1), including the states and larger cities Schleswig-Holstein, Mecklenburg-Vorpommern, Hamburg, Niedersachsen, Bremen, Brandenburg, Berlin and Sachsen-Anhalt, generally offer favourable possibilities for an efficient supply for population and industry with high quality drinking and industrial water. Altogether around 1.4 - 1.5 x 10^9 m^3/a of water are consumed in North Germany, of which around 90% are taken from ground water resources. The use of the ground water however is restricted by geogenic as well as manmade pollutions.

Ground water salinization is a latent threat to ground water utilization in large parts of North Germany. Despite a reduction in the ground water production, which was a result of water saving strategies (since the 80ies) and the strong recession with a resulting decline of industrial production as well as water saving strategies in the former German Democratic Republic (since the end of the 80ies), a slow increase of salinization can be observed in many areas. This give hints that no stable system has been reached yet.

Therefore an estimation of the utilizable ground water resources, the distribution of salt water and the hydrochemical composition of the salinized areas and the surroundings as well as the dynamics of the salt-/freshwater interface is important and has to be intensified.

Ground water salinization in Northern Germany

The main reasons of geogenic salt contamination of ground water resources in North Germany are the intrusion of sea water, dilution from salt diapirs and the upconing of deeper ground waters (CARLÉ 1975). Subrosion and upconing deeper ground waters are here called „inland salinization". The relevance of injected wastewaters from oil- and gasproduction is difficult to estimate, since up to now only little information exists about their influence. Other geogenic sources of salinization, as the

Geogenic background concentrations for chloride in fresh ground water range between 10 and 20 mg/l and sulphate concentrations are even lower. In areas with concentrations higher than 50 mg/l an influence of salinization can be stated. Maximum concentrations reach some hundred g/l. In general chloridic and sulfatic ground water salinizations can be differentiated. Types of salinized ground water and ground waters influenced by salt water occuring in Northern Germany as well as classifications are described by MÜLLER (1966), LÖHNERT (e.g. 1967), CARLÉ (1975), GERHARDY et al. (1976) and others. In contrast to high chloridic concentrations sulfatic salinizations are restricted to the vicinity of caprocks of salt diapirs and generally only have a minor extension.

Maps of ground water salinization exist for all parts of North Germany, but an overview is missing (see Fig. 3). In the German Democratic Republic (today representing the states Mecklenburg-Vorpommern, Brandenburg and Sachsen-Anhalt) a map series in 1:50.000 included detailed information on salinization in relationship to the different aquifers, the depth of the interface and the location of salt spots. Recent largescaled maps in different scales have been drawn for the former German Democratic Republic (REINSCH et al. 1990), Niedersachsen (HAHN 1991b) and Schleswig-Holstein (GRUBE et al. 1996). The existing maps use different definitions for salinization and salinization categories and so cannot directly be compared to one another. Detailed maps (1:25.000) of the concentration and hydrochemical composition in the upper aquifers have recently been published for the area of the town of Bremen, which allow a thorough interpretation of geogenic sources of salinization as subrosion, river bank infiltration and salt water intrusion as well as man made influences (ORTLAM & SAUER 1993).

Our newly drawn map of which a part is shown in Fig. 2 can be used to illustrate the general distribution of ground water salinization as a result of geohydrological structures and processes. Geogenic salinizations are found in the following main natural situations:

- salt water intrusion at the coast (mainly lowland areas)
- large discharge areas (large valleys and lowland areas) with upconing as a result of upward directed potential gradients
- large Tertiary Basins and other geological depressions, with decending salt waters (gravity effect), probably mainly due to subrosion of salt structures
- local hydraulic connections of deeper salinized to higher aquifers through eroded or primary missing aquitards (e.g. Elsterian dorrs) in aquifers with ascending ground waters
- upconing of deeper ground water along faults or equivalent hydraulic pathways through aquitards
- discharge of ground water with higher salt concentration (possibly connate waters) from outcropping older strata.

Investigation Areas

Recent research is carried out in different regions of the north german lowlands with its softrock aquifers (Fig. 1). Three large areas have been choosen as main research fields: Hamburg, Potsdam and Lübeck. These show varied forms of salinizations (see below) and are representative for large parts of the North German Lowlands. Besides that a number of other areas will be investigated, e.g. in Bremen and at places at the North Sea and the Baltic Sea coast. In the following a brief description of the research areas will be given.

The investigation area Hamburg is situated in the marshes of the Elbe valley, a large ice marginal spillway, which represents a large extrusion area. To the north and south of the valley pleistocene till

flooding during tidal waves, the deposition of salts via sea spray in coastal areas, the concentration of shallow subsurface waters by evaporation processes as well as the influence of naturally high salt concentrations of rivers only play a minor and local role.

A number of detailed investigation programs on the distribution and the quality of salinization were carried out in the former German Democratic Republic (e.g. VOIGT 1972, GLANDER et al. 1975, REINSCH 1976). Possibly the most detailed investigations on ground water salinization in North Germany have been carried out on possible nuclear disposal sites in salt domes (e.g. OCHMANN & FIELITZ 1993, VOGEL et al. 1993). Actual examples of research on advanced modelling techniques on salt water upconing in the former East Germany are shown in DIERSCH & NILLERT (1990) and NILLERT et al. (1988). In the coastal area intensive investigations in Niedersachsen since the sixties have to be mentioned (see HAHN 1991a for details and literature), a recent example of a typical coastal ground water salinization in Niedersachsen is shown in ROGGE & JOSOPAIT (1993). In Schleswig-Holstein intensive studies were carried out in the western coastal region (e.g. NEUMAYR 1979; see also literature in GRUBE et al. 1996). Altogether hundreds of scientific papers have been published on numerous areas and many specific aspects of ground water salinization problems in Northern Germany. These are at the moment summarized and evaluated to establish a state-of-the-art report.

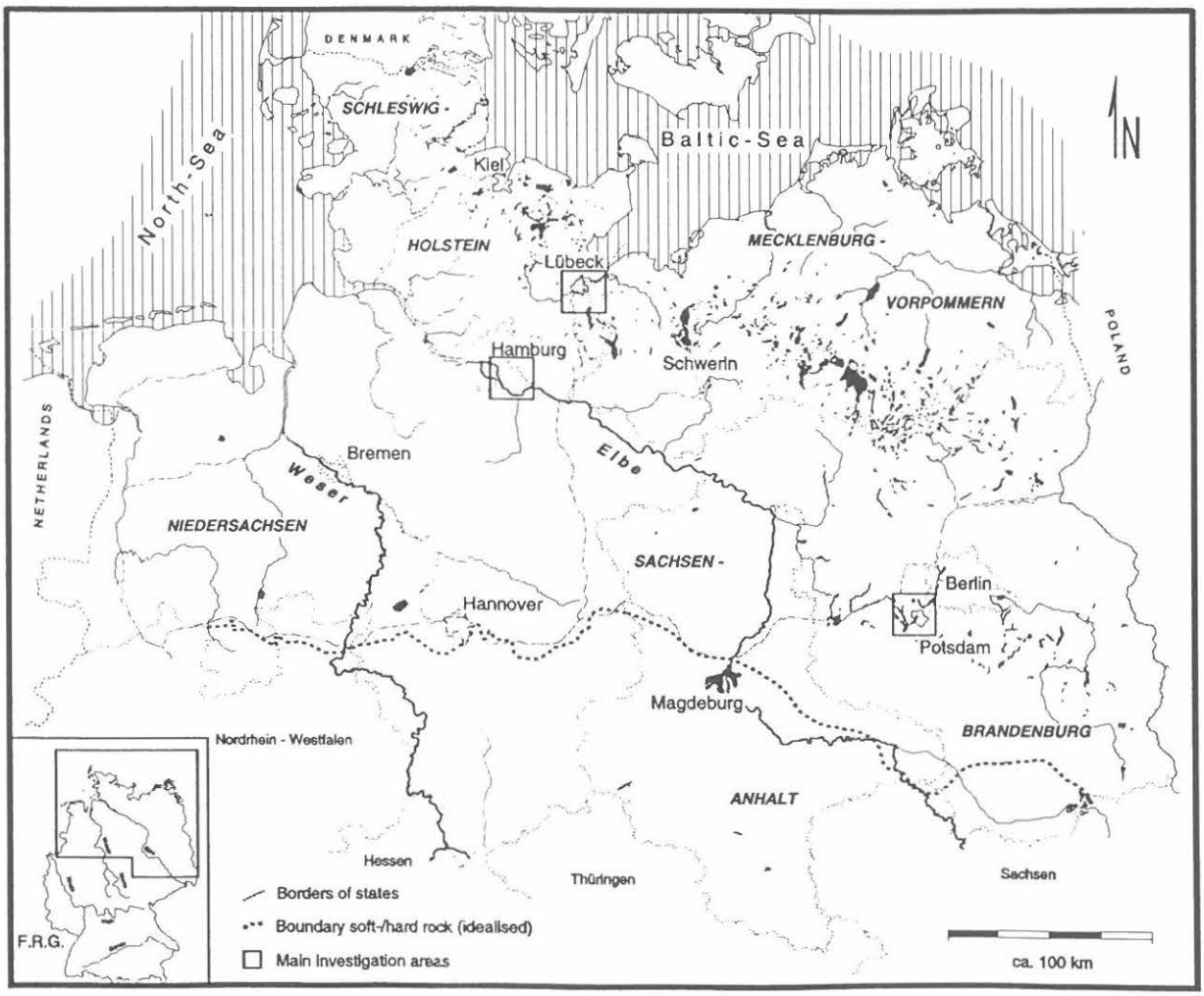

Fig. 1. North German lowland areas and main investigation areas

areas are found. The basis of the aquifer system is build up by silty fine sands of the Vierlande-formation (Lower Miocene). The lowest usable aquifer are the lower lignite sands (Braunkohlensande) which are separated from the upper lignite sands (both Miocene) by the Hamburg clay. The lower lignite sands comprise a series of Miocene fluvial sediments that show dispersed browncoal components and browncoal horizons as well as silty to clayey layers. The Hamburg clay is an aquitard of a few meters in thickess that is present over large area. Nevertheless it shows erosional gaps also, e.g. large Elsterian dorrs cut through this aquitard. The extended silt-horizons in the lignite sands make the hydraulics much more complicated. Above this series Saalian tills and sands occur and on top of these Weichselian fluvial sands reach a thickness of some tens of meters. Holocene perimarine silts, peats and fluvial sediments build up the surface layers. In the western part of the investigation area (Wilhelmsburg) the geological conditions are similar but here a large dorr is plugged by pleistocene clayey sediments and the neighbouring upper mica clay. The distribution of the ground water salinzation is rather complicated. In the eastern part it occurs mainly in the lower lignite sands, but reaches into the Elsterian to Weichselian aquifers also. Salt spots in the highest aquifers reach some thousand mg/l chloride. The salinizations are probably due to subrosion, possible source salt diapir for the eastern part of the area are the structures Meckelfeld or Reitbrook. Recently an increasing of salinization in the city's aquifers has been stated (FREIE UND HANSESTADT HAMBURG 1996). The higher mineralized ground waters are connected to a large salinization area following the Elbe valley upstream southeast of Hamburg. One of the main questions is if saltwaters from a salt structure can ascend despite of a large clayey sediment sequence at the basis of the utilizable aquifer. In Wilhelmsburg (source diapir: Othmarschen-Langenfelde) the salinization is reaching from the upper lignite sands into the lower lignite sands via an Elsterian dorr. Besides that river bank infiltration of the Elbe river and deepwell reinjections may have an additional influence. For details see BAUHUS (1986), EHLERS & GRIEGER (1985), HAHN (1991b), LÖHNERT (1981) and SCHULZ & WICHMANN (1985).

Potsdam is situated in the southwest of Berlin. Ground water salinization is a widespread phenomena in this region which at the beginning of the 80ies even has led to a critical situation in the city's water supply by the main waterwork (RECHLIN & ZÜHLKE 1994). Overexploitation in some areas today results in an increase of salinization in pumped ground water despite of a reduction in withdrawl. The basis of the utilizable aquifers is generally build up by the Rupel clay (Middle Oligocene). On top of this other middle Oligocene sediments and different Pleistocene (Elsterian to Weichselian) aquifers and aquitards are found. Both confined and unconfined ground waters occur (BLUMENSTEIN & VOIGT 1991). Dilution of the upconing salt water takes place with meteoric infiltration water as well as bank infiltration from lakes and rivers. The ground water salinization is the result of upconing deeper ground waters (pre-Rupel), which migrate through erosional gaps in the Rupel clay cover. These hydraulic pathways are build up by Pleistocene erosional dorrs, which are filled with varied redeposited Tertiary and Pleistocene material of sandy to clayey composition. Towards the Earth's surface different tills form a complicated pattern of aquitards. The underground flow patterns of the diffusive salinized ground waters towards existing water wells are therefore in some areas difficult to trace. In some parts upconing water appears as salt spots at the surface of valleys.

Lübeck is situated at the southern end of a large Tertiary basin. The base of the aquifers utilizable for ground water extraction are silty fine sands of the Vierlande-formation. On top of these the lower lignite sands are found. The lower parts consist of fine, sometimes silty sands. The Miocene sands are discordantly overlain by different pleistocene sediments with a sandy to clayey composition. Tills of Saalian age and Weichselian clays which were deposited in the large glazilacustrine Lübeck Basin form widespread aquicludes (JOHANNSEN 1980). Ground water salinization which occurs in the lignite sands as well as in the Quaternary sands is probably due to subrosion (source salt diapir still in discussion) and upconing deeper waters, possibly older formation waters. The fine grained lower parts of the lignite sands in some parts show higher salt concentrations which might result from

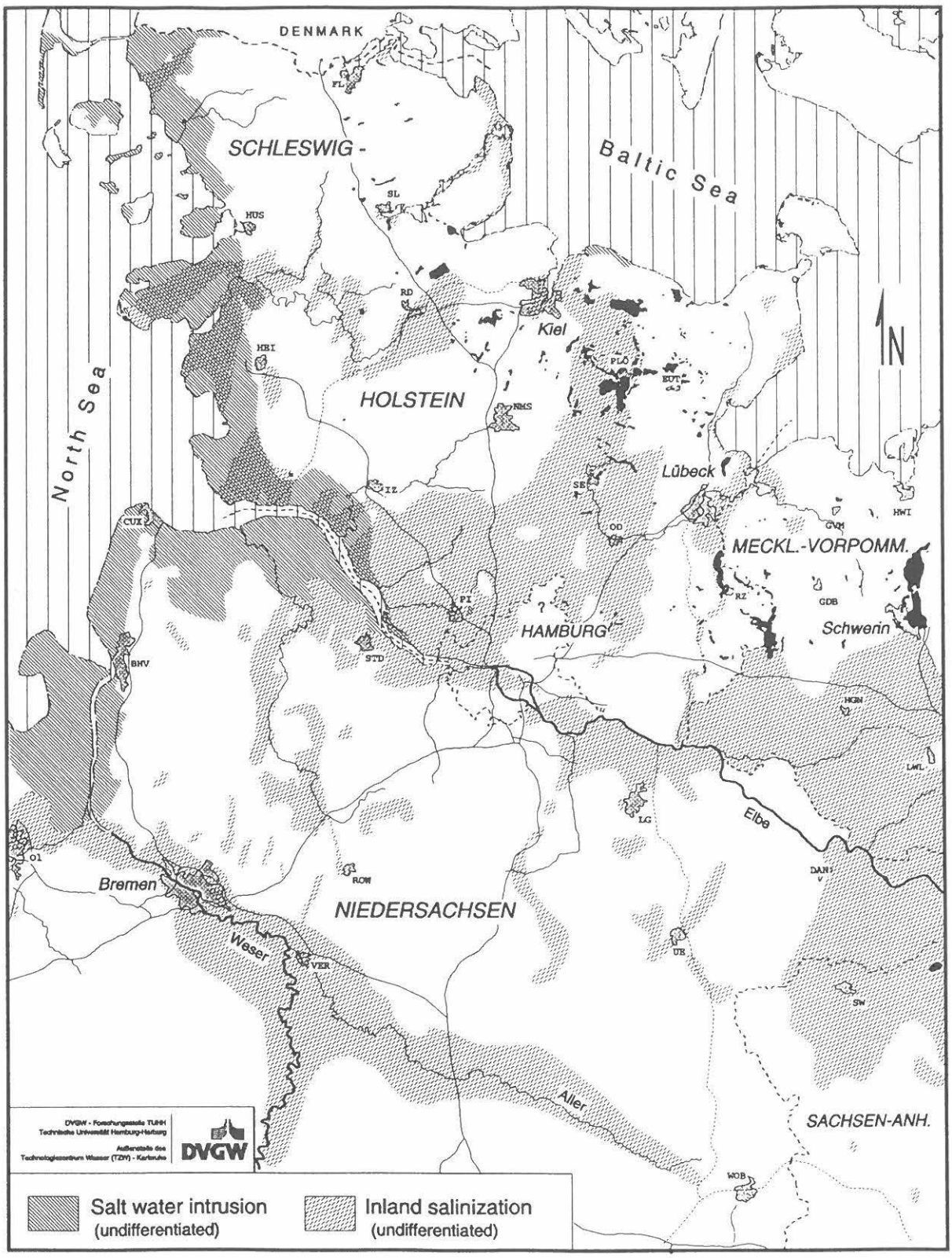

Fig. 2. Ground water salinization in the western part of Northern Germany (draft map; source: GRUBE et al. 1996, HAHN 1991b, REINSCH et al. 1990). The criteria used to define the distribution of salinizations vary in the different sources used for the map. The final map will cover North Germany as a whole and will in the future be developed towards (i) a homogeneous definition on what will be shown as salinization, (ii) the distribution of salinization in different aquifers and depths, (iii) differentiation between subrosion and upconing deeper ground water and (iv) the position of salinization areas towards water works.

grainsize dependend effects. At the coast a small scaled intrusion of seawater from the Baltic Sea can be estimated. Possible additional sources of salinization are the salts from the Trave river and man made pollutions. The geogenic salt concentrations in Lübeck increased especially in the sixties and seventies as a result of steadily growing ground water extraction. A maximum upward movement of the fresh-/saltwater interface of up to 40 meters in 35 years occured (SCHENCK in JOHANNSEN 1980). Because of water saving policies and a period of recession in industrial production the water consumption decreased and the drawdown areas recovered. Nevertheless in some parts of the region salt concentrations are still slowly rising.

Investigation Program

For the assessment of the influence of the salinization on the utilizable ground water resources intensive studies will have to be carried out. For this task a working group has been formed, which consists of the professionals concerned with ground water issues in the Watermanagement Authorities and Geological Surveys of the five large states and the cities Hamburg, Berlin and Bremen, as well as large Water Supply Institutions (Fig. 3). Colleagues from the Universities of Hamburg, Kiel, Münster and Berlin will also be working together. Finally a number of other institutional and private persons are included into the regional research projects.

Generally the investigations can be differentiated into three levels: (I) largescaled screening (softrock areas of North German Lowlands), (ii) regional research of hydrological units (Hamburg-Elbe valley; Untertrave / Lübeck region; Potsdam) as well as (iii) local detail studies of single catchment areas or waterworks settings (waterwork Hamburg-Curslack, waterwork Kuden in W´Schleswig-Holstein and others).

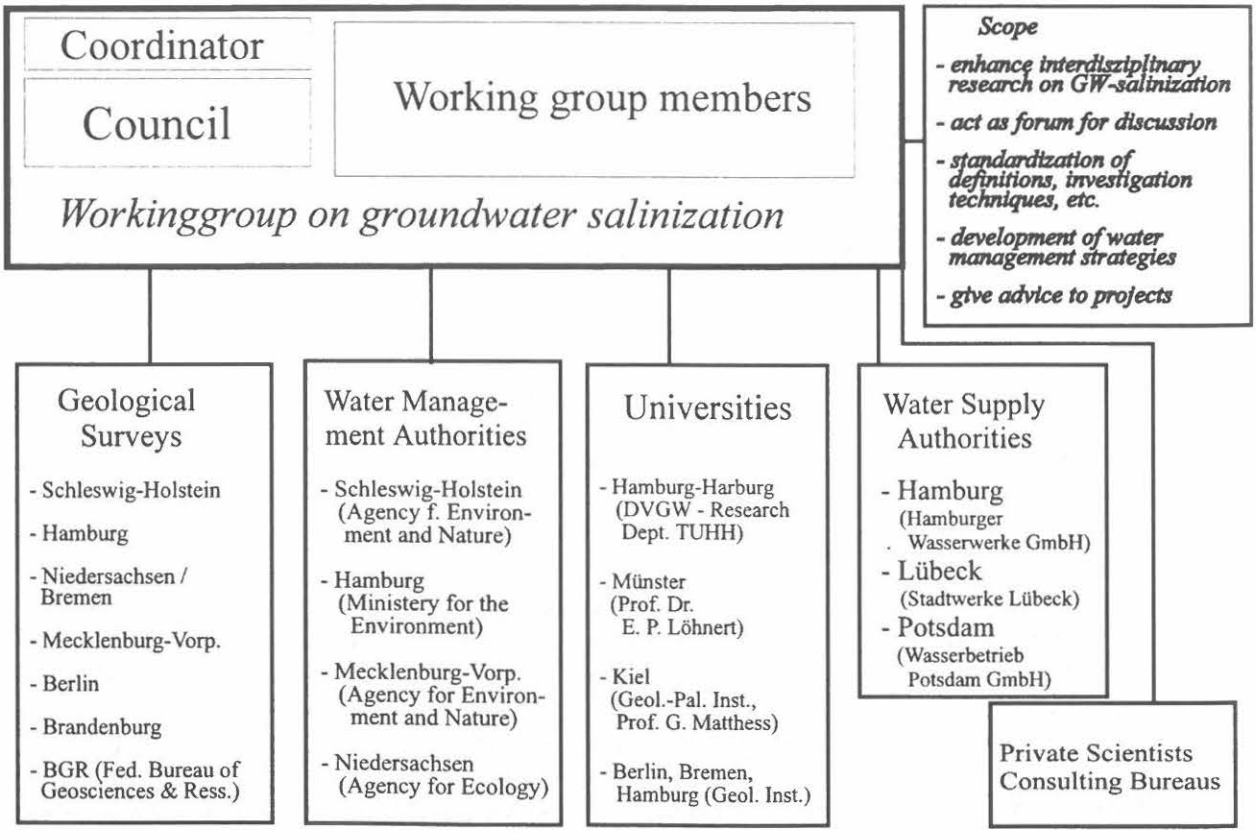

Fig. 3: Structure of the Working Group on Ground Water Salinization

The scope of the working group can be summarized as follows:

- As a basic need the existing data have to be validated and verified (correlation of filterposition and aquifers, ground water level data, geophysical measurements, hydrochemical data etc.). Because of the large amount of data automatic procedures (e.g. numeric and graphical approaches) will have to be enhanced or developed.
- Work on genetical aspects and type classification of salt water and salinized water
  a. methodical questions of genesis
  b. type classification and presentation
  In this context a scope for the classification has to be defined. Based on this the development of models / diagrams has to be carried out. Aspects of salt water genesis, rock-water interaction and manmade influences have to be considered
- The saltwater-/freshwater interface, for which a standardized definition is needed, will have to be worked on towards its configuration and its time and space dependent behaviour. These largely depend on regional ground water dynamics, the petrographical composition of the aquifer as well as manmade influences (e.g. drainage or ground water withdrawal).
- Another important scope is the systematic work on the dynamics of saltwater bodies in its relation towards physical parameters like density, temperature and potential flow direction as well as the structure of the aquifer systems
- Distribution pattern of salinized and fresh waters in regional hydrological units in which the temporal development and influencing factors represent central questions
- To distinguish aspects of salt water genesis and the occurrence of mixture of different ground waters (e.g. upconing deeper ground waters of different origin with fresh water) also hydrochemical models and classifications of fresh waters and mixed waters in the vicinity of ground water salinizations play an important role
- An important aim of the work is the development, standardization and further improvement of (a) measurement techniques (e.g. density problem during water table measurements), observation well configuration, geophysical surveying etc., (b) data evaluation/statistics and (c) ground water monitoring
- These results will be used in water management strategies in the vicinity of fresh-/saltwater bodies with the aim of a sustainable use of ground water resources
- Map presentation of salinized ground waters and salt water bodies requires the development of adjusted and standardized legend, scale and nomenclature
- An additional aspect is the necessity for an increased consideration of paleohydrological and paleohydrogeological issues.

An interdisciplinary research approach is needed to solve salinization issues that are becoming even more important because of a tendency to intensify the utilization of deeper aquifers. A better understanding of geogenic ground water salinization phenomena can also add to an objective discussion on man made interference with our shallow aquifers. New water management methods have to be developed for the Watermanagement Authorities in the relevant areas, replacing older „strategies“ (e.g. relocation of wells) which will allow for a longterm sustainable use of our ground water resources.

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