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HYDROCHEMICAL ASPECTS OF THE INTERFACE

SUMMARY

The main aquifer in the northern part of W-Germany (Schleswig-Holstein) is formed by unconsolidated sands of the Tertiary Age, which are part of the large sedimentary accumulation in the synsedimentary troughs between the salt diapirs in the deeper underground. Saline Water with increasing salinity lies underneath the freshwater layer. The reasons for this are saltwater intrusion in the coastal areas and dissolution of salt from the salt diapirs in the central areas.

Base exchange processes which take place mainly upon contact of freshwater and saline water cause the origin of exchange water. Due to the exchange process aggressive water, formed by free CO₂, is found in the interface zone, which causes a further dissolving of mineral components. - Often exchange water is combined with colour producing organic substances which are disturbing agents in drinking water.

1. INTRODUCTION

The large increase in the demand for groundwater in the northern part of W-Germany (Fig. 1) as well as in other urbanized regions in the last 30 years has not yet led to any difficulties in the supply of drinking water. However

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there are increasing problems as a result of chemical composition of the groundwater in the transmission zone between saline and freshwater (interface zone), which limits the use of groundwater as drinking water.

This paper deals with observation – and investigation – results of this phenomenon as seen by hydrogeologist working with the applied sciences.

The water supply in Schleswig-Holstein is produced by groundwater wells, which are in some cases more than 300 m deep and which have screens in the water bearing sediments of the Tertiary and Quaternary ages. The main aquifer (Fig. 2) is widely distributed and is formed by «lignite sand» of the Miocene and the «caolin sand» of the Pliocene. These sands are part of the large sedimentary accumulation in the synsedimentary troughs between the salt diapirs in the deeper underground. The unconsolidated quartz sands have a medium to high permeability. The Tertiary beddings are covered by an average of 40 - 80 m of Quaternary sediments, mainly sand and glacial till.

The age of the groundwater is till a few thousand years old measured by radio carbon C^{14} . Normally the groundwater is found in an oxygen free, reduced state.



Fig. 1 - Geographical position

Saline water with increasing salinity lies underneath the freshwater layer. The reason for this are saltwater intrusion mainly in the western coastal area and dissolution of salt [2, 3] from the salt diapirs in the central area.

The depth of the interface is generally dependent on the groundwater stream conditions in the main aquifer. The groundwaterflow (Fig. 3) is controlled mainly by the topography, secondly by the drainage system and of course by the bordering Baltic and North Seas. In recharge areas the interface lies deep below the surface and in discharge areas sometimes lies directly under the surface.

Most problems with the groundwater use are found in discharge areas with a shallow interface, because it is here that the most cities and towns were settled in the course of history.

2. CHEMICAL COMPOSITION OF THE GROUNDWATER

2.1. Freshwater

The dissolved solids in the freshwater (Table 1) range from 130 to 300 mg/l. The calcium-ions and hydrogencarbonate-ions are predominant and are present in approximately equivalent amounts. Both range from 4 - 5,5 mval/l, which corresponds to a hardness of the freshwater from 4 to 15° dH. Therefore the hardness of the freshwater is almost exclusively carbonate hardness.

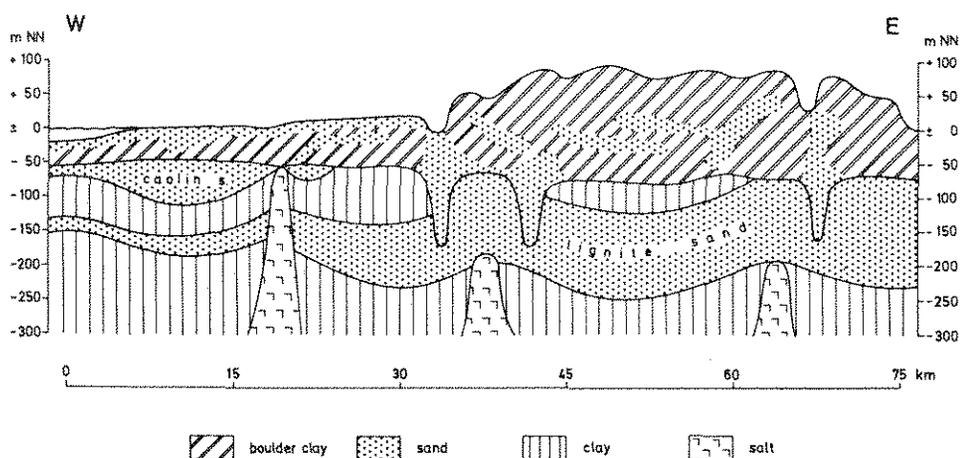


Fig. 2 - Geological cross section

In general the freshwater is in equilibrium with the carbondioxide-bicarbonate-carbonate system with moderate alkalinity.

2. 2. Saline water

The groundwater situated under the interface is a moderately saline water. Normally a few hundred to a few thousand mg/l dissolved solids are found through analysis. The saline components are mainly Na-Cl-ions. In some cases sulphate-ions are found depending on the seawater intrusion or on the presence of gypsum on top of salt domes.

As a result of mixing processes between the saline water and the freshwater there exists a large range of various type of groundwater mineralization.

2. 3. Exchange water

Ionic exchange processes which take place mainly upon contact of fresh water and saline water in the interface zone cause the origin of exchange water (Table 1). This exchange water normally is developed by the exchange of the cations Na^+ for Ca^{++} . In general as a result of the hydrogeological situation in Schleswig-Holstein a type of groundwater with a significant content of sodium-hydrogencarbonate is formed.

The necessary conditions for the existence of exchange water dependent on the hydrogeological situation are described below:

a) the presence of natural permutites (mainly mica and humus substances in fine sand and silt with less permability)

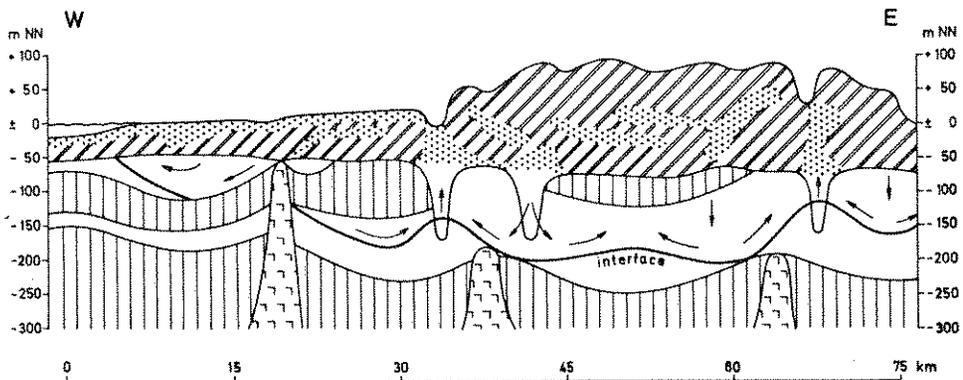


Fig. 3 - Hydrogeological cross section and groundwater flow

- b) large contact surface between groundwater and permutite
- c) long contact time between groundwater and permutite
- d) complete saturation of the aquifer pores with groundwater

During the cation exchange process the alkali ions (mainly Na^+) are exchanged for alkali-earth-ions (mainly Ca^{++}) of the saline water. The exchange process takes place according to the following reaction:



Due to the exchange process the temporary hardeners are changed into an equivalent amount of NaHCO_3 , resulting in soft water.

An amount of free CO_2 is not necessary to maintain the carbondioxide-bicarbonate-carbonate equilibrium of NaHCO_3 in comparison to $\text{Ca}(\text{HCO}_3)_2$, therefore the total free CO_2 becomes aggressive. This process causes a further dissolving of mineral components in the water bearing sediments, especially a dissolving of calcium if this is present.

TABLE 1 - Chemical composition of the different types of groundwater

	fresh w.	saline w.	exchange water	
			humic subst.	« aggressive »
P_H	7,1	7,4	7,6	6,0
Na^+ mg/l	8	2290	170	310
Ca^{++} mg/l	43	316	85	72
Mg^{++} mg/l	12	31	14	44
Cl^- mg/l	18	2357	189	205
SO_4^- mg/l	15	41	0	132
NO_3^- mg/l	0	0	0	4
GH° d.H.	10,7	25	7,7	12,2
KH° d.H.	9,5	15	16,8	12,2
CO_2 free mg/l	12	18	9	27
CO_2 aggr. mg/l	1	0	0	133

Not yet published results [4] of hydrochemical investigations of groundwater samples, (Table 1), in the interface zone show that a very large amount of aggressive CO_2 can be produced (max. 278 mg/l) in the area of the interface-zone. Under these conditions not only calcium but also heavy metals can be dissolved. The results from the interface area, defined by Cl^- -contents of roundabout 200 mg/l show that iron, manganese, zinc, nickel, cobalt and copper can be dissolved, while lead, cadmium and chromium are not dissolved.

Under specific hydraulic conditions dissolved heavy metals are transported to the fresh-water layer. Here the heavy metals will precipitate, because of the changing of the chemical balance due to the buffering of aggressive CO_2 . That means: increasing the pH and oxidation-reduction potential-value. These investigations could be confirmed by geochemical analyses of sediments. In the precipitation - zone the sands of the aquifer were found to have a coating of heavy metals, while in the interface - zone the sand grains were mostly free from the mentioned metals and even the quartz grains showed corrosion effects on their surface.

4. HUMIC SUBSTANCES AS DISTURBING AGENTS IN DRINKING WATER TREATMENT

In many cases exchange water is affected by colour producing organic substances, since most likely amorphous humic substances are very probably colloiddally dissolved as Nahumates due to the exchange of cations in the interface-zone. As a result of peptisation humic substances take part in ground-water mineralization. The humic substances are soluble in alkaline conditions and can only be coagulated by addition of acids or high-charged cations like Fe^{3+} or Al^{3+} .

Though humic substances [1] don't show any toxic qualities, they are considered to be disturbing agents in drinking water and therefore must be separated from groundwater.

Particular difficulties in water treatment arise for ferruginous and manganese groundwater in the presence of humic substances. On the one hand chemical complex combinations between metal-ions and humic substances are possible. These combinations prevent the desired oxidation and hydrolysis of the metal ions as well as their coagulation and sedimentation as hydroxides. On the other hand the effectiveness of the gravel packed surface area of installed deferrization and demanganization filters can be reduced by additional accumulation of humic substances. Even in very low quantities of humic substances of 2 - 3 mg/l the deferrization capacity is clearly diminished.

In general the treatment of groundwater which contains colour producing organic substances is very difficult. Because of the various modifications of organic colours, there are no known methods of treatment which are generally accepted.

Mainly the following 4 methods for the treatment of groundwater containing humic substances are available:

- sedimentation
- filtration
- oxidation
- adsorbtion

For the determination of the capacity of a treatment plant extensive experiments are usually necessary.

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