The salinization of useful Cenozoic aquifers by ascending Mesozoic brines – characterization on the basis of hydrochemical data from northern and central Poland

Dorota Kaczor–Kurzawa
Polish Geological Institute – National Research Institute, Kielce, Poland

ABSTRACT

Synthesis of hydrochemical data, concerning 12 000 chemical analyses from HYDRO Bank Database of Polish Hydrogeological Survey, was used to formulate a quantitative estimation of groundwater salinization process which occurs within Cenozoic aquifers as a result of the ascent of diluted brines from Mesozoic formations. The data allowed to forecast the potential salinization hazard of Major Groundwater Basins and major groundwater intakes.

INTRODUCTION

The ascent of diluted brines from Mesozoic formations to Cenozoic useful aquifers leads to groundwater salinization which causes a real threat to groundwater quality and disposable reserves on substantial areas in northwestern and central Poland.

The aim of this paper is to discuss the origin of geogenic groundwater salinization within the Cenozoic aquifers, and to present the forecast of salinization hazard to Major Groundwater Basins and major groundwater intakes. The study area (40 000 km^2) corresponds to the area of well developed salt tectonics forms within the Permian-Mesozoic complex (Figure 1).

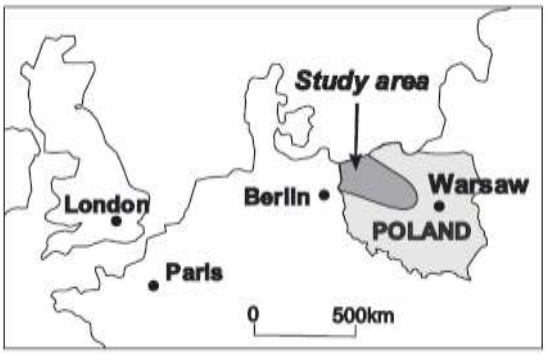

Figure 1. Location of the study area

METHODS

The characterization of groundwater salinity in Cenozoic deposits is based on over 12 000 chemical analyses collected in HYDRO Bank Database of Polish Hydrogeological Survey (Polish Geological Institute). The assessment of reliability of water data for individual Cenozoic aquifers relied on elimination of those results of analyses which could indicate that water salinity was caused either by Baltic seawater ingressions or by anthropogenic pollution. Particular attention was paid to the results of analyses of groundwater extracted for public use in cities where the probability of anthropogenic pollution of groundwater is high. The basic indicator of anthropogenic origin of chlorides in groundwater is an increased concentration of sulphates and nitrogen. Measurements showing the amount of nitrates in water of >0.1 mg/dm^3, and that of sulphates of >40 mg/dm^3 in confined aquifers, and 75 mg/dm^3 in unconfined ones, were rejected.

The variation in salinity displayed by groundwaters from Cenozoic layers was compared against the background of the tectonic setting of Permian-Mesozoic formations, and a scheme of groundwater circulation system in Cenozoic deposits. Chemical analyses, measurements of stable oxygen and hydrogen isotope ratios were done for groundwater samples collected in areas above selected fault zones and salt tectonic structures, which allow for upward migration of brines under pressure along the tectonically produced pathways.

RESULTS

Synthesis of hydrochemical data conducted for the best recognized part of the study area, in NW Poland (26 000 km^2), allowed a quantitative estimation of groundwater salinization process occurring within Cenozoic aquifers (Kaczor 2006). Similar data synthesis is currently being prepared for the central Poland area. The resultant *„Maps of distribution of increased chlorides concentrations in Quaternary, Paleogene and Neogene aquifers"* present the distribution of groundwater salinization zones within Cenozoic aquifers (Kaczor 2006).

A groundwater salinization zone within a Cenozoic aquifer is defined by a group of wells with concentration of chloride ion in water exceeding (> 60 mg/dm^3 – for Quaternary, and > 70 mg/dm^3 – for Neogene and Paleogene aquifers) upper limits of hydrogeochemical background values. In the described part of NW Poland, such increased concentrations of chlorides were recorded in almost 800 wells, and the total area of confirmed salinity is 8600 km^2, i.e. 33% of the whole area of interest.

According to presented forecast, the upward migration of brines is hazardous to groundwater quality of 4 out of 20 Major Groundwater Basins, and to 16 among 31 major groundwater intakes yielding more than 100 m^3/h of water, located in the investigated area of NW Poland. The described regional synthesis of hydrochemical data helps to choose suitable areas and to project research concerning salinization problems affecting some specific intakes.

Szubin communal intake (yield 1000 m^3/d), located in Kujavian region in Central Poland, can serve as an example (Figure 2, 3).

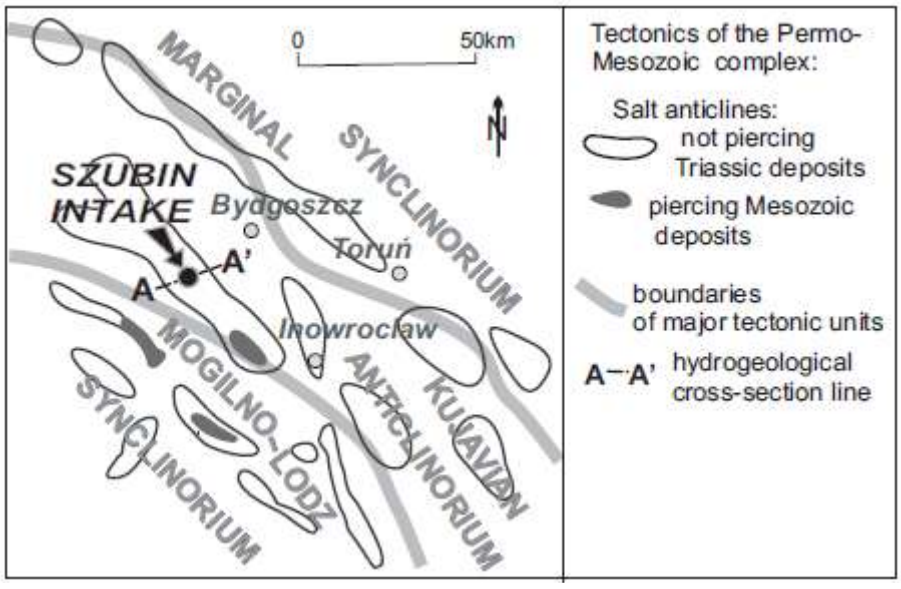

Figure 2. Location and tectonic situation of Szubin intake

Groundwater of this intake is characterized by the chlorides content exceeding accepted norms for drinking water (250 Cl mg/l). The maximal chlorides content was examined in wells nr 4 (510 mg Cl/l) and 6 (540 mg Cl/l).

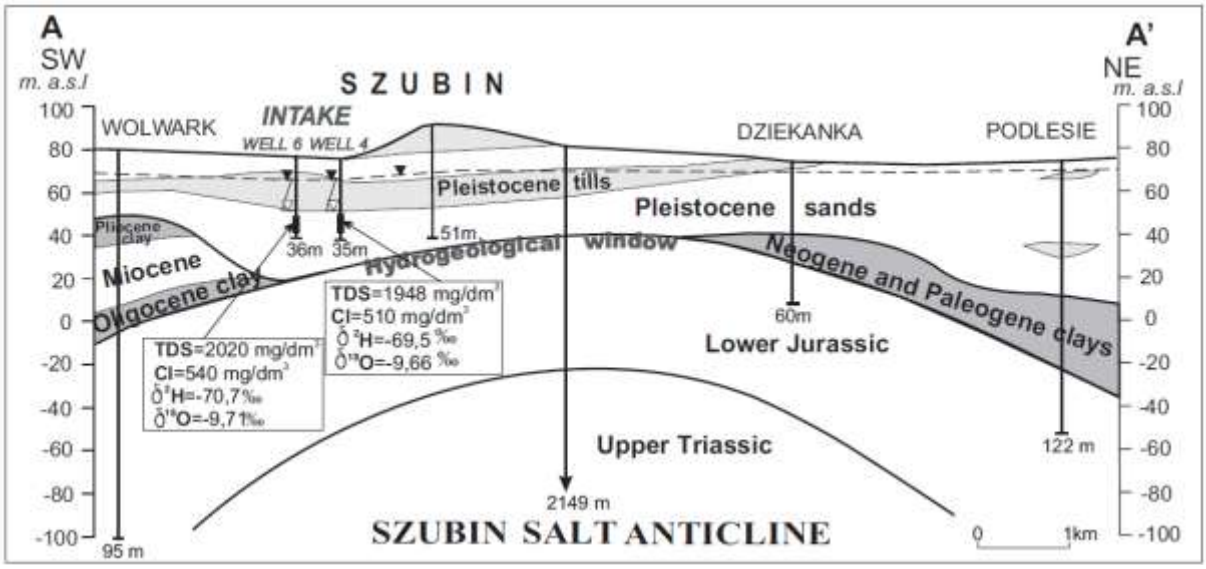

Figure 3. Hydrogeological cross-section and tectonic situation in vicinity of Szubin intake

This groundwater is mixed with groundwater of better quality, coming from other wells, before the introduction to the communal water-pipeline. The salinization of groundwater at this intake was caused by upward migration of saline water from the Mesozoic complex. Such conclusion is supported by the results of measurements of stable oxygen and hydrogen isotope ratios (Figure 4), suggesting that the examined groundwater contains an admixture of "older" waters, which have migrated from the Mesozoic rocks.

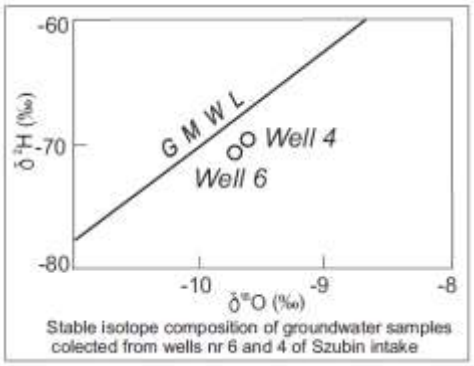

Figure 4. Stable isotope composition of investigated waters

The hydrogeological window, existing on the crest of Szubin salt anticline (Figure 2, 3), all ows an ascent of saline waters from Jurassic towards the Cenozoic aquifer.

DISCUSSION AND CONCLUSIONS

The saline waters within the Mesozoic formation are under pressure, which enables their upward migration through a system of fractures and faults towards the Cenozoic aquifers (Dowgiałło et al. 1990). This process is most intense in hydrogeological windows developed in areas of erosional reduction of the overlying Paleogene and Neogene clays on uplifted tectonic blocks and salt-cored anticlines. Such hydrogeological windows are considered the main zones of brine ascent in northern Germany (Grube et al. 2000).

The extent of groundwater salinity zones in Cenozoic aquifers is dependent on flow directions of groundwaters which dilute the brines migrating upwards from Mesozoic rocks. That is why the areas of confirmed salinity are not always coincident with the groundwater ascent zones.

Salinity of groundwaters in the described Cenozoic aquifers is not a result of the currently ongoing process of dissolution of the Zechstein salt bodies, because they are mostly isolated from the groundwater active circulation system. This observation does not correspond to numerous examples of dissolution of salt diapirs during the Holocene reported at northern Germany (Grube et al. 2000). Only a few cases of Zechstein salt structures leaching, during the Cenozoic period, have been confirmed in Polish Lowland, and concern several diapirs piercing through the Mesozoic rocks. The role of salt structures in the process of groundwater salinization relies primarily on the fact that areas of reduced thickness of clays, isolating saline groundwaters from fresh groundwaters, occur above the crests of salt core anticlines.

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Contact Information: Dorota Kaczor–Kurzawa, Polish Geological Institute-National Research Institute, ul. Zgoda 21, 25-953 Kielce, Email: dorota.kaczor-kurzawa@pgi.gov.pl