

## Salinization of the Świnoujście groundwater body (Polish part of Uznam Island)

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### ABSTRACT

The Uznam Island is situated at the mouth of the Odra River on the southern Baltic Sea coast. The eastern part of the island that belongs to Poland is known from the shortages of potable water. The water supply is covered by groundwater pumped from Quaternary aquifer up to 50 m depth. Brackish groundwater of Cl-Na type and TDS over 40 g/l from the Lower Cretaceous strata is used for the therapeutic purposes in the Świnoujście Spa. Exploitation of water intakes causes encroachment of salt waters from the sea coast and also ascension of salt water from the Mesozoic strata into the Quaternary aquifer.

### INTRODUCTION

The continuous increase of population and holidaymakers has caused the increase of flow ratio of groundwater intakes on the Uznam island. Location of water intakes, spa and sampling points are shown on fig. 1. Rising salinity of groundwater has been observed since 1995 yr. There is possibility that Cl<sup>-</sup> concentration increase comes from the sea water intrusion or by ascension of brines from the Mesozoic strata. These brines and salt waters are used as therapeutic waters in the Spa.

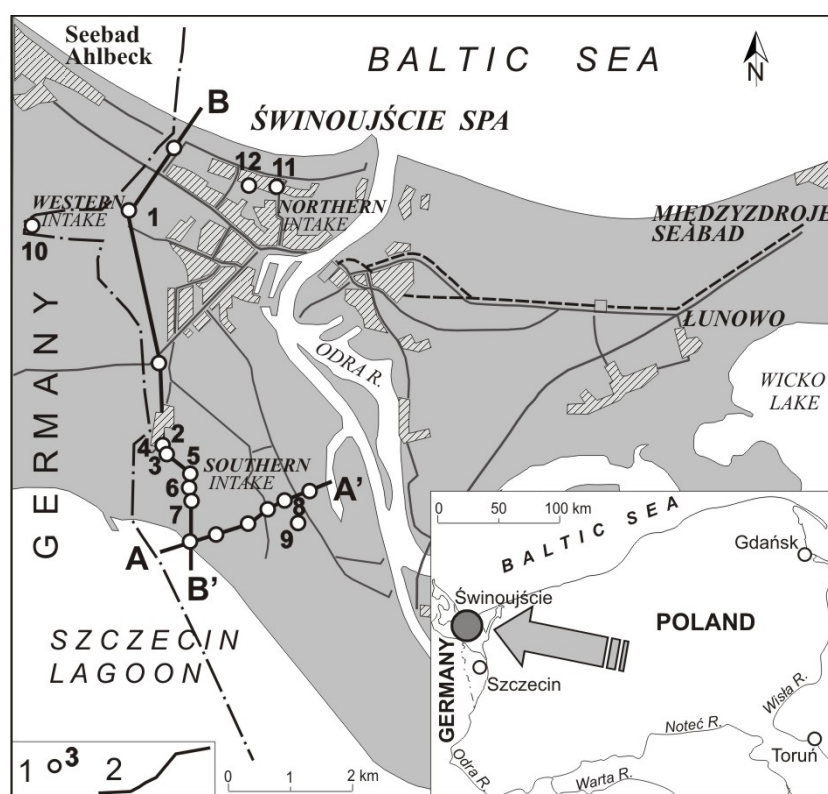
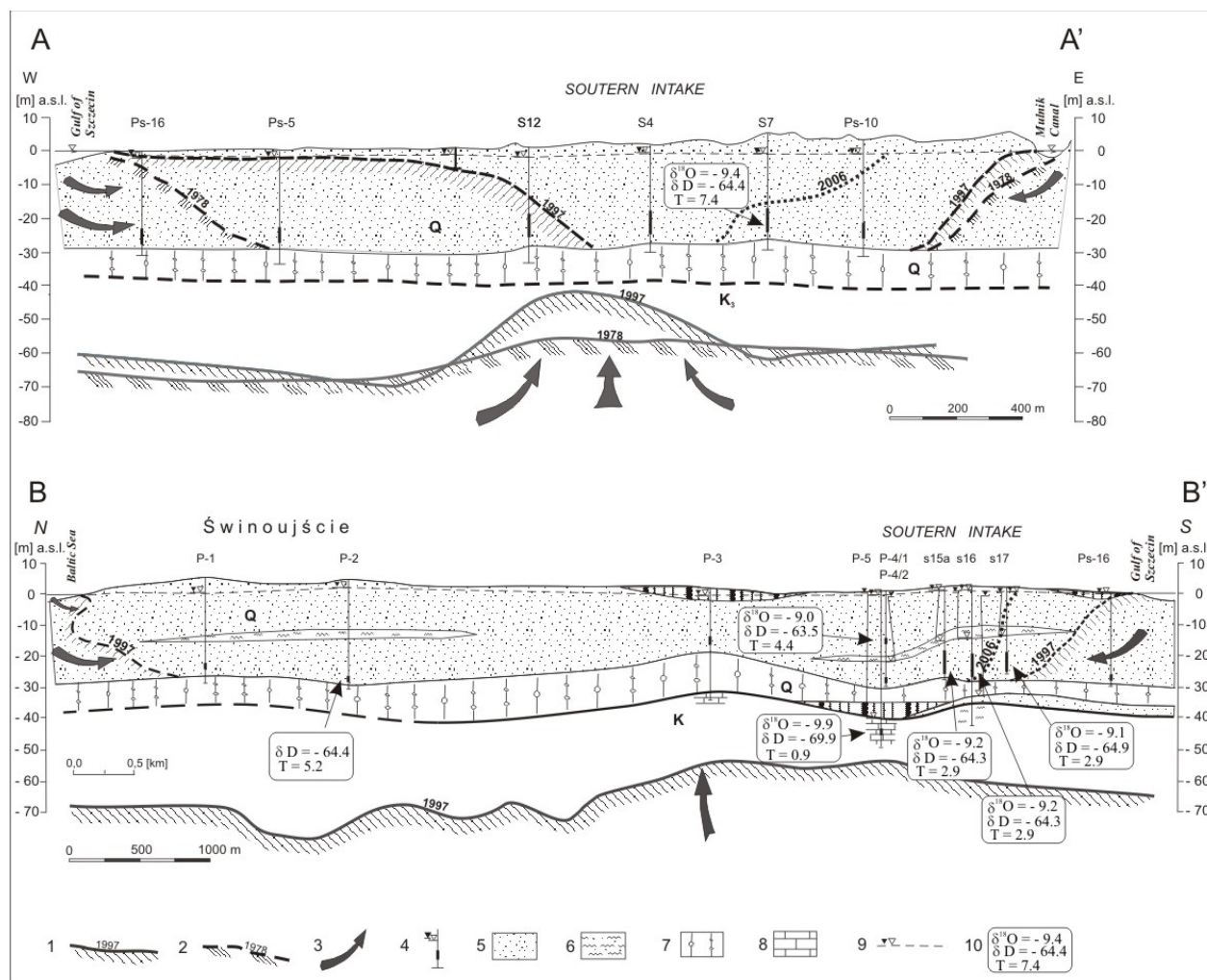


Figure 1. Location of the investigated area  
1 - sampling points, 2 - hydrogeological cross-sections line

## METHODOLOGY & RESULTS

Explanation of the salt water origin in the Quaternary aquifer was based on the results of isotopic and chemical composition of groundwater. Samples were taken from wells screened in Pleistocene and Upper Cretaceous strata at depth from 15 to 50 m. Values of  $\delta^{18}\text{O}$  and  $\delta\text{D}$ , tritium and radiocarbon were established for the groundwater samples. Locations of sampling points are given on fig. 1. The geoelectrical logging was used twice during field investigations, first in the area of groundwater intakes in 1978 and second in 1997 (Kucharski, Tkaczyk 1997). Additional geoelectrical imaging was done in 2006. The zones of ascending salt water and ranges of sea water intrusions were established based on results of these investigations, which is shown on fig. 2.



**Figure 2. Hydrogeological cross-sections and changes of salt/fresh water limit according to geoelectrical logging in the eastern part of Uznam Island:**

- 1 - zone influenced by salt water, above 3000 mgCl/l; 2 - zone influenced by salt water, from 300 to 1000 mgCl/l; 3 - saline and brackish water inflow; 4 – well/piezometer; 5 - sands, 6 - muds, 7 – glacial tills, 8 - marls, 9- grounwater table, 10 - investigation results;  $\delta^{18}\text{O}$  and  $\delta\text{D}$  values, T – noble gas temperature, Q - Quaternary; K – Cretaceous

According to the isotopic composition investigation, the saline groundwater of the eastern part of Uznam Island belongs to the contemporary, meteoric and infiltrational waters. Nevertheless, these groundwater have signiftc differences in many points, as it can be noticed in table 1 and on figure 3. Water samples no 1, 2, 8 and 9 represent infiltrational water and samples taken from points no 12 have the “relic” component and are influenced by ascension of saline water from Mesozoic strata.

The average residence time of groundwater is in a range of 200-300 yr. The water sample from point 5 has 2,9 TU and belongs to the present infiltrational water. Concentration of helium  $^4\text{He}$  in investigated groundwater proves that, residence time is longer than 200 yr and that water is likely to come from the early Holocene times (Krawiec *et al.*, 2000). The higher values of chloride ion  $\text{Cl}^-$  in water samples taken from wells no 6 and 7 prove sea water inflows to the Quaternary aquifer from Szczecin Lagoon. It is also proven by the geoelectrical logging results as given on fig. 2.

The isotopic composition of groundwater pumped on the western water intake – sample no 10 - has changed over the last 10 yrs. The values of  $\delta^{18}\text{O} = -9.46\text{‰}$ ,  $\delta^2\text{H} = -64.4\text{‰}$ , were recorded in year 2000, but at these values are  $\delta^{18}\text{O} = -9.29\text{‰}$ ,  $\delta^2\text{H} = -63.1\text{‰}$ . Also, the concentration of  $^3\text{H}$  diminished from 8,0 T.U. to 5,7 T.U. over that time. It is concluded, that intense extraction of groundwater on the Island caused more intense circulation.

The results of  $\delta^{18}\text{O}$  i  $\delta^2\text{H}$  investigations in sample no 11 from a well situated in Świnoujście Spa show that infiltration to the Cretaceous aquifer took place in the period of cool climate from the end of Pleistocene and in early Holocene. This water sample contains high chloride concentration up to 8 800 mg/l, which testifies the ascension of brines or salt waters from deeper Mesozoic strata. The isotope composition and the noble gas temperature distribution both show that infiltration to these strata was possible in Pre-pleistocene times.

**Table 1. Hydrochemical data, available isotope and noble gas data for water samples taken from western part of Uznam Island**

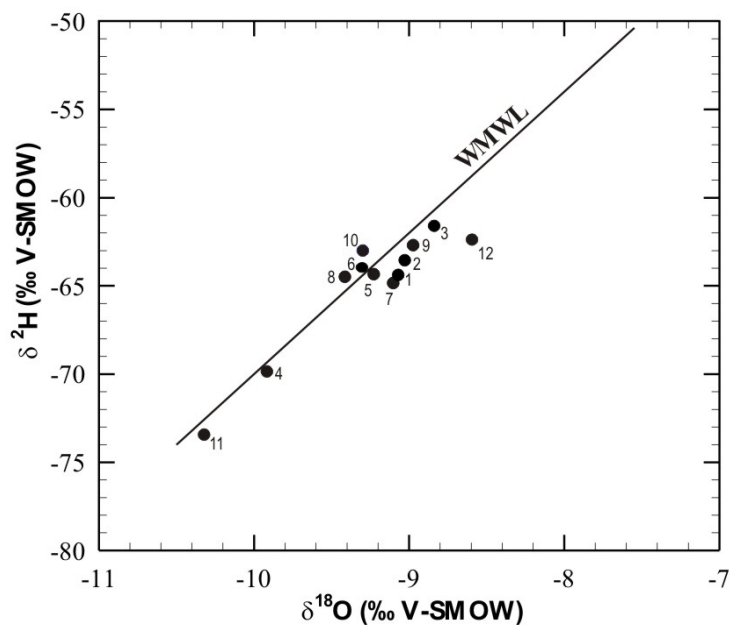
Lp.	Name of sampling site, Strat./depth [m]	Time of sampling	$\text{Cl}^-$ [mg/l]	Tritium $^3\text{H}$ [TU]	$\delta^{18}\text{O}$ VSMOW [‰]	$\delta^2\text{H}$ VSMOW [‰]	$^{14}\text{C}$ [pMC]	Noble gas temp. NGT [°C]	$^4\text{He}_{\text{excess}}$ $10^5$ [cm <sup>3</sup> /g]	“Ages” of ground water
1	Świnoujście P-2, Q/33	2005	46	5,2±0,4	-9,07	-64,4				M
2	Świnoujście P-4/1, Q/17	2005	56	4,4±0,4	-9,02	-63,5				M
3	Świnoujście P-4/2, Q/31	2005	21	0,3±0,3	-8,83	-61,6				
4	Świnoujście P-5, Cr/50	2005	873	0,9±0,4	-9,91	-70,0	91,5±1,0			
5	Świnoujście Soutern s15a, Q/29	2004	28	2,9±0,3	-9,22	-64,3	61,5±1,0	10.3	0.083	H
6	Świnoujście Soutern s16, Q/30,5	2005	329	0,9±0,4	-9,30	-64,0				H
7	Świnoujście Soutern s17, Q/30	2005	360	2,9±0,4	-9,10	-64,9	60,5±1,0			H
8	Świnoujście Soutern s7, Q/34	2000	183	7,4±0,5	-9,40	-64,4		8.2	0.059	M
9	Świnoujście Soutern s8a Q/31	2004	513	10,9±0,6	-8,98	-62,7		7.9		M
10	Świnoujście Western SD-2, Q/45	2005	36	5,7±0,5	-9,29	-63,1		8.3	0.026	M
11	Świnoujście IIIs, Q-Cr/90	2004	8794	0,1±0.3	-10,30	-73,3		5.8	64.93	pG
12	Świnoujście V, Cr <sub>1</sub> /240	1998	25171	-	-8,60	-62,4				pQ

“Age” classification: M – modern (atomic bomb era), H – Holocene (pre-bomb Holocene), G – glacial, pQ – pre-Quaternary. Uncertainty (standard deviation) of:  $\delta^{18}\text{O}$  is  $\pm 0.1\text{‰}$ ,  $\delta\text{D}$  –  $\pm 1\text{‰}$ , NGT –  $\pm 0.7\text{°C}$ ,  $^4\text{He}$  excess –  $\pm 10$

The geoelectrical logging done across the island also proves that groundwater resources are in danger of salt water intrusion (fig. 2) The isotopic composition of groundwater samples were examined over the period 1988 – 2005 (tab. 1). With respect to results of noble gas and  $^4\text{He}$  concentrations, differences of the residence time has been noted, which results from extensive groundwater exploitation by extraction.

**Figure 3. Stable isotope composition of investigated waters ( $\delta^{18}\text{O}$ - $\delta^2\text{H}$  relationships). Chosen samples are identified by numbers given in table 1**

The isotope composition ( $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ ) of the brackish groundwater samples taken from the bottom part of the Quaternary and upper part of the Mesozoic aquifers, makes the evidence of long term circulation and recharge into the aquifer during the early, colder part of the Holocene. The residence time of water in the Cretaceous aquifer is estimated to be more than 7 000 yrs ago. The contemporary salty water intruding to the exploited aquifer are of sea origin. Rate of this intrusion increases significantly during summer season on the Baltic coast, when a demand for water supplies doubles due to increased number of people visiting the area.



## CONCLUSION

Groundwater resources of Uznam Island are in danger of salinisation caused by saline water ascension from the deeper Mesozoic aquifer and the sea water intrusion along the coast of the island. The northern water intake on the island was stopped in 90s, due to high chloride concentrations coming up to 3 900 mg/l. It refers mainly to water intakes situated close to the shore line and Szczecin (Odra) Lagoon. The geoelectrical logging allowed to mark the interface line on the cross-sections. This logging, repeated at intervals of few years, proved the vertical and horizontal movement of interface surface between saline and fresh water (fig. 2).

The isotope composition and NGT of the investigated groundwater enables to explain the  $\text{Cl}^-$  origin in the Quaternary aquifer. Saline water from the ascension has lower values of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  but brine occurring in deeper Cretaceous strata has the highest value of  $\delta^{18}\text{O}$  along the polish coast aquifers. NGT results show that groundwaters of deeper aquifers had infiltrated in different climate conditions, as from the end of Pleistocene and early Holocene and in sampling point 12, even from Pre-Quaternary times. Fresh water pumped from the western water intake does not inform about the salinisation process, but the residence time of this water is about 200 yrs and the point is situated in the recharge area.

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