SPREADING OF BRINE DISCHARGED INTO THE PUCK BAY (SOUTH BALTIC SEA): THEORETICAL STUDY VERSUS FIELD OBSERVATIONS

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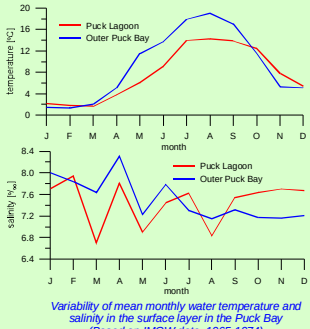
General information

Increasing demands for gas storage capacity encouraged Polish Gas and Oil Company (PGNiG) to make use of salt deposits located in the north-eastern part of Poland, in the area bordering on the Gulf of Gdańsk (South Baltic Sea), and create underground gas stores. A complex of 10 chambers (250x10^{6}m^3) was designed to be built at a depth of 800-1600 m. The construction site is located about 4 km away from the sea coast. The drilling of boreholes and diluting of salt rock was proposed as a method of creating the chambers. Owing to ecological reasons, maximum discharge of brine is limited to 300 m^3/h with the maximum saturation of 250 kg/m^3.
The main difficulty of the investment lay in the effective spreading of brine in the Puck Bay (inner part of the Gulf of Gdańsk) in accordance with all requirements that apply to regions protected by NATURA 2000. The most important restriction was the permitted excess salinity, defined as 0.5 PSU over the natural salinity in the Puck Bay.
The Puck Bay is a shallow western sub-region of the Gulf of Gdańsk separated from the open sea by the Hel Peninsula. In the middle of the Hel Peninsula there is a shallow sand-bank which divides the Puck Bay into two parts differing in circulation patterns: the eastern one (the Outer Puck Bay; av. depth 20.5 m), and the western (the Puck Lagoon; av. depth 3 m). Currents in the region are generated mainly by wind and the accompanying water level variations in time and space.
The water temperature in the Puck Bay is climate dependent and modified by the inflow of marine and fresh waters, mainly from the Vistula River. Seasonal thermal stratification is observed in the Outer Puck Bay. Water salinity in the Puck Bay is determined by interactions between marine and fresh waters. In the Outer Puck Bay, salinity is closely related to the inflow of more saline water from the Gdańsk Basin. In addition, the surface layer is modified by fresh water from the Vistula River.

Study area with chosen location of discharge and scheme of diffusing system designed by EMPORIUM

Working diffuser



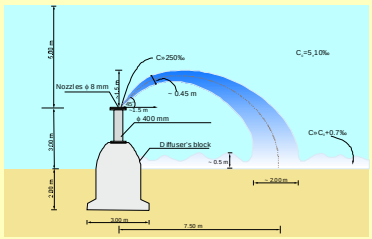
Variability of mean monthly water temperature and salinity in the surface layer in the Puck Bay (Based on IMGW data, 1965-1974)

Pre-investment analysis of brine discharge, modeling approach modeling approach

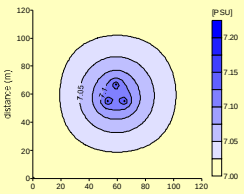
To assess the influence of the proposed installation on the surrounding environment analysis covered the following issues:
- kinematic parameters of the brine jet coming from a single nozzle;
- mixing conditions for a single jet in the surrounding water;
- the spreading of brine in the nearfield of a diffuser;
- the spreading of brine in the Puck Bay.

Exemplary results of analyzed kinematic parameters and mixing conditions for a single jet in the stagnant water of 7 PSU (calculations by Deltares)

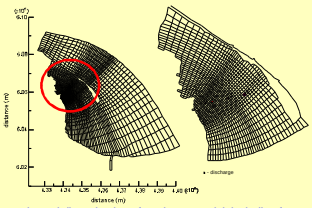
Nozzle diameter	Pressure in pipeline	Discharge	Initial velocity at discharge	Dilution factor	Excess salinity
[m]	[MPa]	[m^3/s]	[m/s]	[-]	[PSU]
0.020	0.075	0.00348	11	96	2.5
0.010	0.305	0.00173	22	220	1.1
0.009	0.460	0.00173	27	265	0.9
0.008	0.450	0.00136	27	307	0.8
0.008	0.750	0.00176	35	359	0.7
0.0065	0.450	0.00087	27	360	0.7



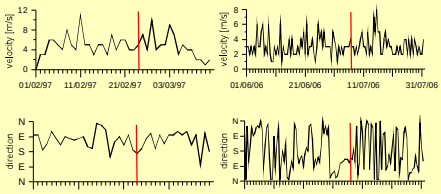
Theoretical behaviour of a single jet of brine in stagnant water



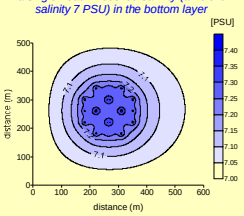
Spreading of brine in the vicinity of a single head: modelled salinity (ambient salinity 7 PSU) in the bottom layer



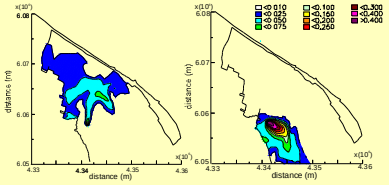
Horizontal discretization of Puck Bay model, including four optional locations analysed (based on Delft3D FLOW)



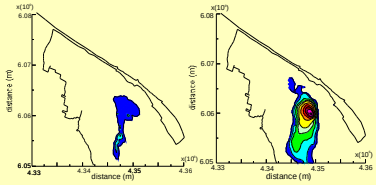
Wind conditions in two analyzed periods: the winter of 1997 (left), the summer of 2006 (right)



Spreading of brine in the vicinity of the system of heads (ambient salinity 7 PSU): modelled salinity [PSU] in the bottom layer



Salinity increase (in PSU) due to brine discharge in location 1: 25.02.1997 (left), 7.07.2006 (right)

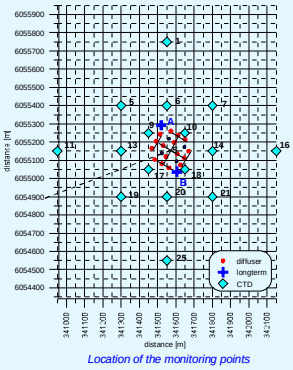


Salinity increase (in PSU) due to brine discharge in location 4: 25.02.1997 (left), 7.07.2006 (right)

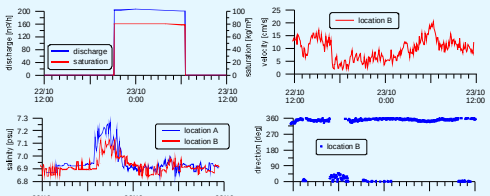
CONCLUSIONS:
Based on theoretical analysis it was decided to build installation consisting of a system of 16 heads spaced every 45 m, each of them equipped with 3 nozzles of 8 mm diameter, and to locate the center of the installation 2300 m off shore

Monitoring in the near-field of installation

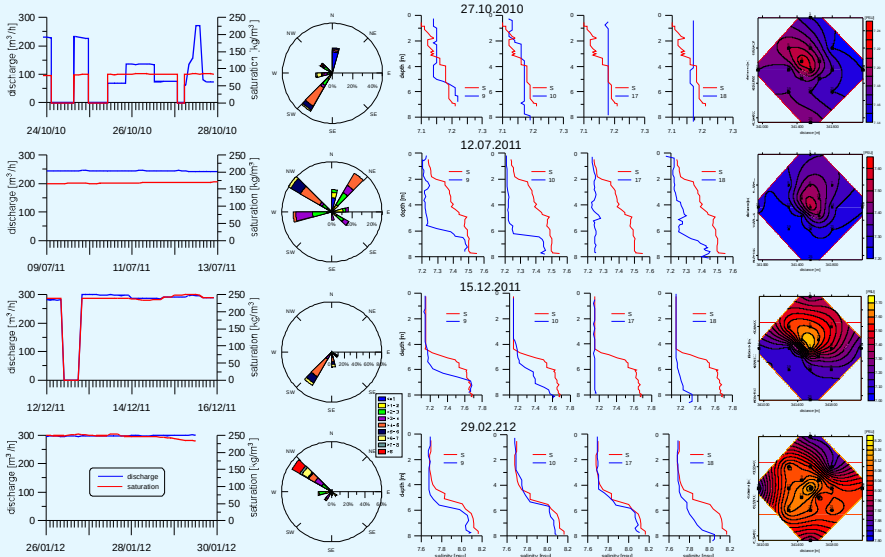
In the summer of 2010, the construction of the brine discharge installation was completed, and on September 20th 2010 its operation started. Since then monitoring of discharged brine started. In the first months of operation salinity measurements in five locations in the nearfield of installation (locations 9, 10, 17, 18 and S) were done once per month. Detailed measurements covering 17 locations were executed occasionally in autumn 2010, and since summer 2011 are done regularly once per month. Some exemplary results from 2010, 2011 and 2012 including characteristics of wind in the region and discharged brine are presented. Moreover longterm continuous registrations of salinity in two locations (A and B) where done in autumn 2010 and summer 2011.



Location of the monitoring points



Characteristics of discharged brine, salnity changes in time, and water currents; Exemplary results from continuous measurements in locations A and B, 22-23.10.2010



Characteristics of discharged brine, wind conditions, and salinity distribution in the nearfield of installation - exemplary results of short term measurements in 2010 and 2011

CONCLUSIONS:
On the basis on measurements carried out in the first period of operation, it can be concluded that the mixing of brine met all the requirements.

Acknowledgement:
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