Analysis of salinity change in the Gliwice Canal and its implications

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Introduction

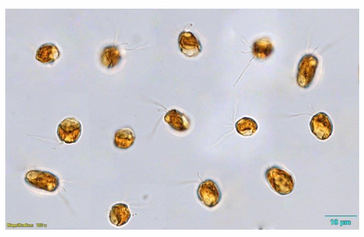
The Gliwice Canal is a hydrotechnic structure consisting of a series of cascade-connected reservoirs, separated by locks. This canal is characterized by poor water quality due to the influx of pollutants through tributaries, such as from urban-industrial drainage basin. One of tributaries is the Kłodnica River, which receives municipal and industrial sewage as well as saline mine waters. Surface runoff from mining waste dumps is also occurring. This river has elevated conductivity and carries brackish waters, worsening the condition of the canal's waters and contributing to its high salinity. In the Gliwice Canal, the decrease in pollutant concentration is mainly caused by dilution (self-purification plays a secondary role) which limits the possibility of quick water purification.

The high salinity has created favorable conditions for the life and reproduction of *Prymnesium parvum* ('golden algae') - single-celled saltwater algae. During sudden changes in water conditions, 'golden algae' produce toxins (prymnesins) under stress. This action combats competition from other species, providing space for further multiplication. The toxins are lethal to fish and other aquatic organisms with gills. It causes that on the Gliwice Canal, there is a risk of potential fish mortality due to the toxicity of *Prymnesium parvum*.

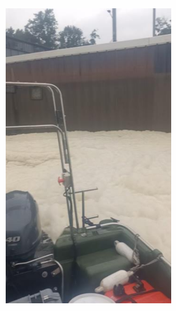
The section of the Gliwice Canal subject to the analysis of salinity changes (12.10.2023)

The image of water mixing in the Gliwice Canal with Rdzawka Stream after rainfall (28.10.2023)

The bloom of 'golden algae' is accompanied by water turbidity, which eventually takes on a golden-brown color.



Prymnesium parvum – fot. J. Kownacka (mir.gdynia.pl/prymnesium-parvum-takze-w-zalewie-szczecinskim/)



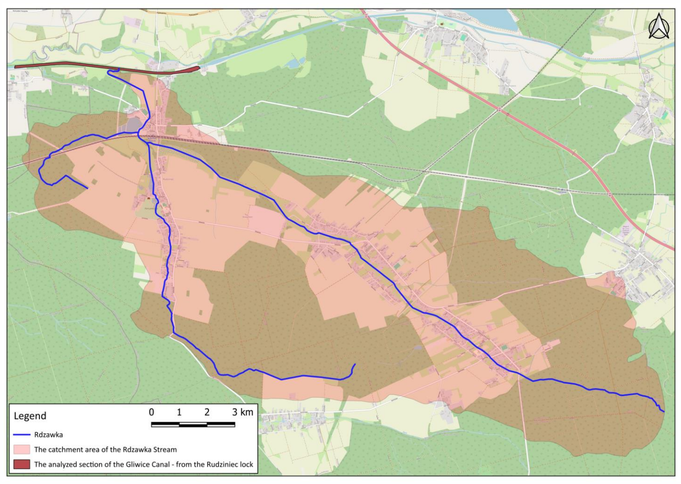
During the research, a characteristic foam was observed, which could indicate the occurrence of a mass bloom of *Prymnesium parvum* (12.10.2023)

Objective of the Study

Prymnesium parvum has potentially very high toxicity for gill-breathing animals such as fish, snails, mussels, or even amphibian larvae. During the previous research, it was observed that the presence of 'golden algae' is not always synonymous with the release of toxins (prymnesins) that are lethal to fish. Currently, trials are underway to neutralize *Prymnesium parvum*.

The aim of the research on the Gliwice Canal was to verify the hypothesis regarding the toxic effects of prymnesins present in the water and those released from *Prymnesium parvum* cells. The hypothesis suggests that toxins are released from algal cells due to changes in osmotic pressure caused by the introduction of freshwater from the Rdzawka Stream into the brackish waters of the Gliwice Canal. The study aims to experimentally verify the possibility of physicochemical conditions that could induce such a phenomenon in the waters of the Gliwice Canal. Based on the models, an attempt was made to determine the areas of *Prymnesium parvum* cell rupture and prymnesins release.

The analyzed section is located near the Rudziniec Lock (km 21+570 of the Gliwice Canal - the last lock in the Silesian Voivodeship) and is approximately 3 kilometers long. This location was chosen due to the reports related to fish kills during the ecological disaster on the Oder River in 2022 and later. As part of the research, an attempt was made to model the dynamics of flows and qualitative changes in the waters of the analyzed section of the Gliwice Canal.



The analyzed section of the Gliwice Canal and the catchment area of the Rdzawka Stream

The confluence of the Rdzawka Stream with the Gliwice Canal (12.10.2023)

The Rudziniec lock (20.11.2023)

Materials and Methods

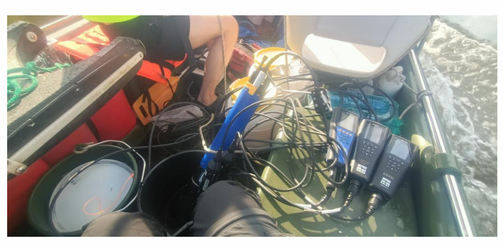
The research work was conducted on-site at the Gliwice Canal and the Rdzawka Stream on 12.10.2023 and 28.10.2023, conducting analyses and collecting measurement data.

Two coupled multi-parameter probes, ProDSS (Xylem YSI), equipped with measurement electrodes, were used. The research locations were determined using GPS spatial location with the use of QGIS 3.32. Analytical buoys were also used. Surfer software from Golden Software was used for interpolating measurement values.

To create a bathymetric map, the Lowrance Elite echosounder and ReefMaster software were used.

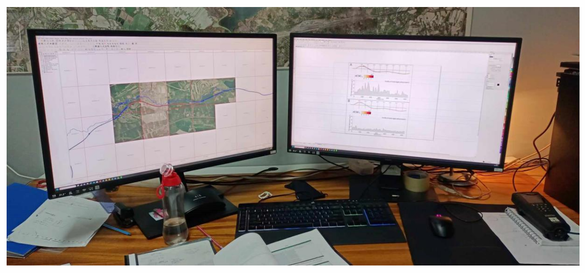
Water quality parameter analysis was based on data obtained from the Chief Inspectorate of Environmental Protection (GIOŚ) and the Regional Inspectorate for Environmental Protection (WIOŚ) in Katowice.

Modeling was carried out using the AEM3D product from HydroNumerics, used for simulating all water resources. This model is based on the globally recognized ELCOM-CAEDYM model developed by the Centre for Water Research. To describe the watershed structure and model the anticipated impact of changes in watershed management practices, the SWAT (Soil and Water Assessment Tool) developed by the U.S. Department of Agriculture was utilized. MATLAB (MathWorks) and The Global Hydrometry Support Facility (WMO HydroHub) were also employed.



The equipment used during field research on the Gliwice Canal (20.11.2023)

Measurement buoys (20.11.2023)

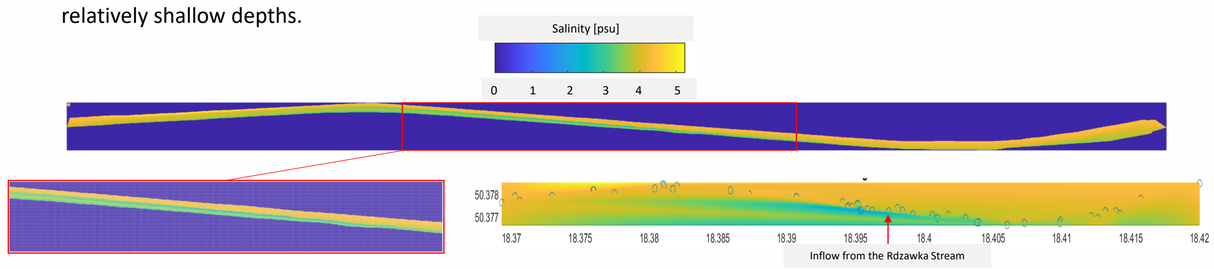


Processing information obtained through measurements and field observations (20.11.2023)

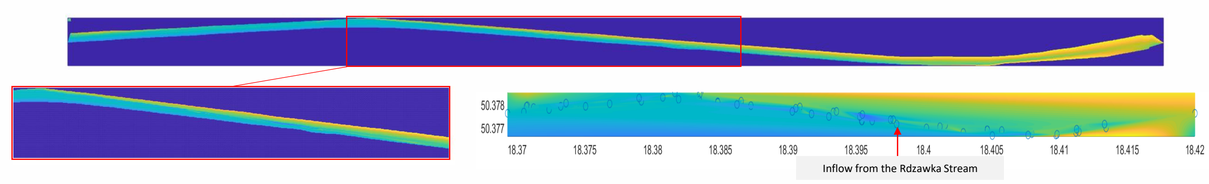
Research Results

The results obtained during field research were interpolated using MATLAB software. The interpolation results indicate the formation of two phases along the Gliwice Canal, resulting from the inflow of fresh water from the Rdzawka Stream into the Gliwice Canal. A decrease in salinity was observed along the southern bank due to the mixing of canal and stream waters. The interpolation results from 28.10.2023, show that the increased inflow of fresh water, caused by surface runoff after rainfall, expands the zone of decreased salinity. The observed mixing of fresh and brackish waters occurs only at the surface of the canal, no mixing was observed at a depth of 1.5 m.

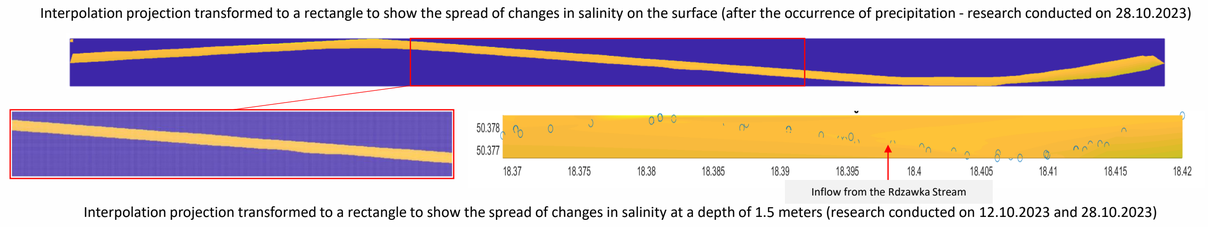
Additionally, a model was created using the AEM3D software. Based on this model, the spread of fresh water in the brackish waters of the Gliwice Canal will be analyzed. Approximately 60 scenarios will be executed, varying in terms of inflows and outflows of the Gliwice Canal and Rdzawka Stream, water temperature, and salinity. These scenarios will demonstrate the extent of the mixing zone under specific conditions in the Gliwice Canal, and thus the extent of salinity values that pose a risk of releasing *Prymnesium parvum* toxins. In the preliminary scenarios, measurement results obtained for the surface layer of water were adopted, as they represent the dominant volume of water in the canal with relatively shallow depths.



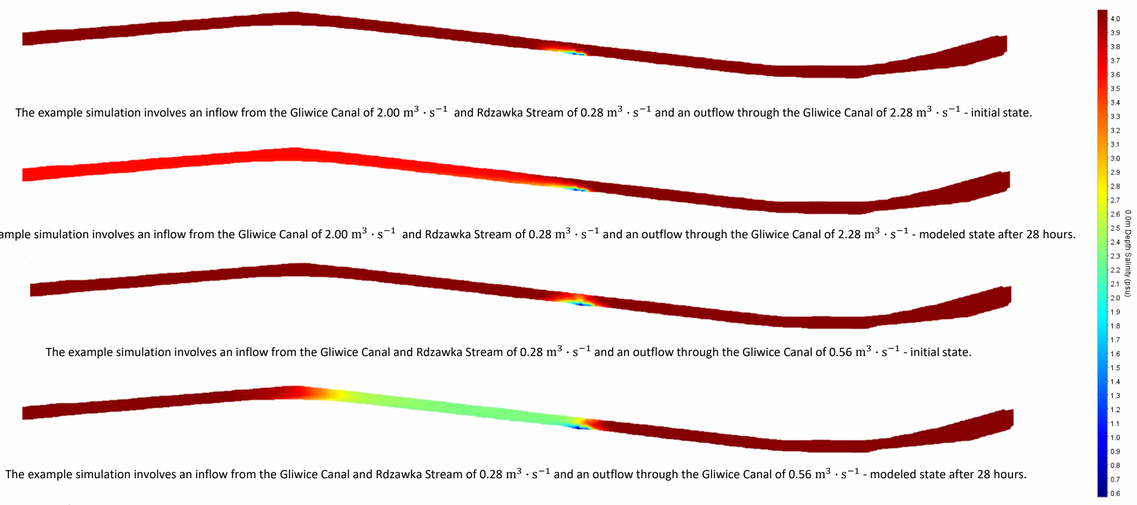
Interpolation projection transformed to a rectangle to show the spread of changes in salinity on the surface (in the absence of precipitation - research conducted on 12.10.2023)



Interpolation projection transformed to a rectangle to show the spread of changes in salinity on the surface (after the occurrence of precipitation - research conducted on 28.10.2023)



Interpolation projection transformed to a rectangle to show the spread of changes in salinity at a depth of 1.5 meters (research conducted on 12.10.2023 and 28.10.2023)



The example simulation involves an inflow from the Gliwice Canal of 2.00 $m^3 \cdot s^{-1}$ and Rdzawka Stream of 0.28 $m^3 \cdot s^{-1}$ and an outflow through the Gliwice Canal of 2.28 $m^3 \cdot s^{-1}$ - initial state.

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The example simulation involves an inflow from the Gliwice Canal and Rdzawka Stream of 0.28 $m^3 \cdot s^{-1}$ and an outflow through the Gliwice Canal of 0.56 $m^3 \cdot s^{-1}$ - initial state.

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Discussion

The model was created to estimate the behavior of salinity in various conditions and times, based on actual data obtained during 2 measurement days.

The research results indicate that the analyzed section of the Gliwice Canal, where the brackish waters of the canal mix with the freshwater of the Rdzawka Stream, creates conditions for high toxicity of prymnesins, posing a threat to the lives of gill-breathing animals. At the confluence of the Rdzawka Stream with the Gliwice Canal, there are flows of freshwater. During inflows exceeding critical value from the Rdzawka Stream, conditions may arise where the life of fish is endangered (not established yet). Salinity in the Gliwice Canal will then reach a value below a critical threshold, at which *Prymnesium parvum* cells, under the influence of osmotic pressure changes, rupture, releasing prymnesins into the environment.

Conclusions

Further research of *Prymnesium parvum* are needed to determine how to manage mass fish kills and other gill-breathing animal species, which lead to ecosystem degradation on a massive scale. Further monitoring of the analyzed section and research into reducing prymnesins toxicity in this area should be considered. Due to the death of organisms involved in the self-purification of the canal, various methods should be considered to restore the environmental state prior to the fish kill in the Gliwice Canal.

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