

WATER QUALITY IN OUTLETS OF THE RIVERS IN SOUTHERN BALTIC COAST AT NORMAL AND EXTREME CONDITIONS

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Introduction

Extensive research on extreme phenomena and their impact on the living conditions of people, their safety and economic and social consequences were initiated in many countries throughout the world many years ago (Crisci *et al.*, 2002). In Poland, research in this scope has been neglected or limited merely to analyses of particular cases, such as the catastrophic flood in Gdańsk in 2001 (Cyberski, 2003). Our country remains a “blank area” on the map of Europe in this respect. The more so, as the current analyses of extreme situations are most often restricted to precipitation and thaw high waters (on land) and storm situations on the Baltic Sea. In the case of the latter, only the hydrometeorological conditions present in the given period on the sea are analysed. What is missing, however, is the information on changes in land water quality within the coast, which is also influenced by the extreme conditions. This is so important as the zone of sea and ocean coasts is a place where on the one hand, phenomena and processes not found in land interior are observed, and on the other hand, the phenomena which occur here have a huge force and dynamics of their course. The most frequent phenomenon, precisely in periods of the occurrence of extreme conditions, are sea water intrusions, observed in various hydrographic objects of the coastal zone, including the mouth sections of rivers (Giambastiani *et al.*, 2007). As a result, a change in the qualitative composition of the waters of these objects is observed, which is manifested mainly in a change in salinity (van der Thuin, 1990). Unfortunately, for Polish coast of the southern Baltic there are only scarce documented examples of the occurrence of sea water intrusion into the mouth sections of rivers and they concern mainly the Wisła and Odra. For the remaining rivers in most cases there is no information on the volume and intensity of the impact of salt waters. Hence, the aim of the paper is the determination whether in the case of the mouth sections of the rivers of the Polish coastal zone of the southern Baltic, the phenomenon of intrusions occurs and if so, whether it occurs in all the rivers and how intense the course and extent of this phenomenon is in particular objects. The objects selected for investigation are the mouth sections of eight rivers or canals of the Polish coastal zone, i.e. the Martwa Wisła, Reda, Płutnica, Piaśnica, Łeba Canal, Łupawa Canal, Potynia and Głównica (Figure 1).

Methods

The main work consisted in collecting water samples for further laboratory analysis. For these purposes, 1 to 9 measurement sites were established on the main objects in the mouth sections of rivers. Only in the case of the Martwa Wisła, the investigation covered the whole course of the river. Monthly investigations were

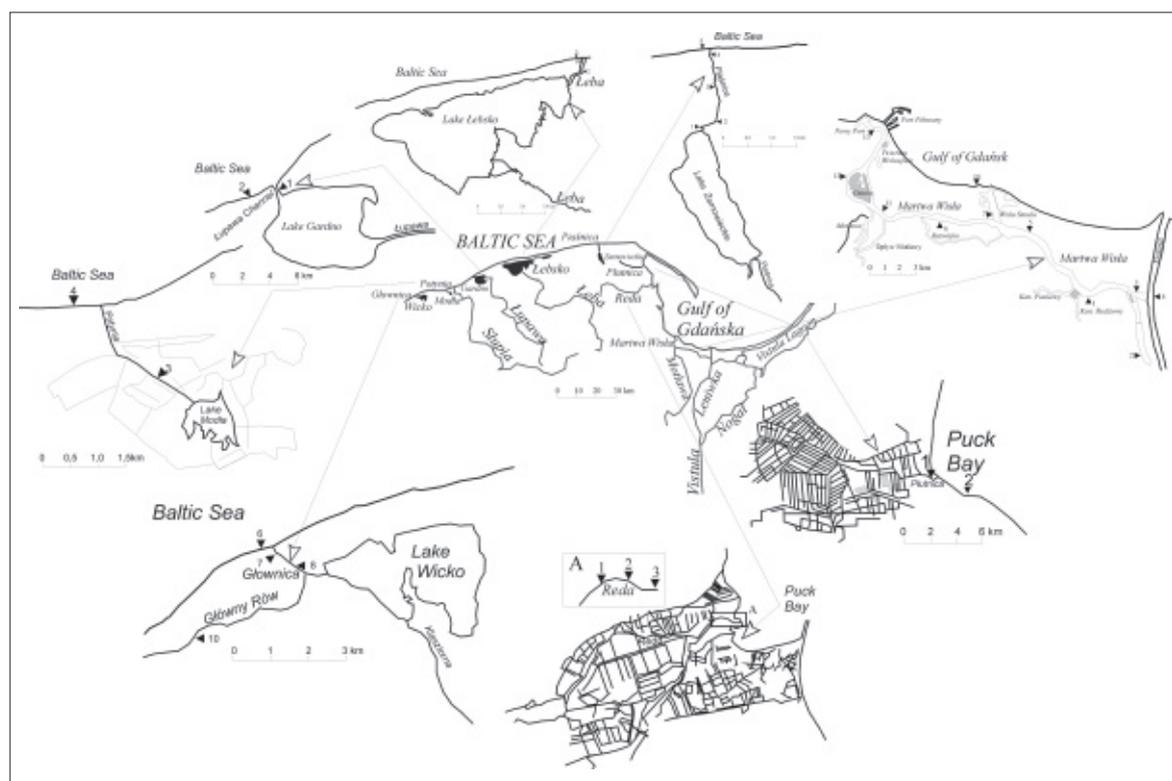


Figure 1. Chosen objects of investigation with localisation of measurement sites

carried out on the River Reda in the period from July 2002 to June 2004, and on the River Płutnica from November 2005 to October 2006. On the rivers Piaśnica, Potynia, Głownica, the Łupawa Canal and Łeba Canal the investigations were performed in the years 2002 – 2007, where a total of 16 collections of water samples were done. The investigation on the Martwa Wisła was performed in the years 2002-2003.

Water samples underwent chemical analysis in the laboratory of the Department of Hydrology of Gdańsk University in order to determine the values of concentrations of basic ions. In this paper only the results of chloride concentrations were used. On the basis of the literature, the threshold value for chlorides, beyond which the phenomenon in intrusion can be identified, was established. This value is $100 \text{ mgCl} \cdot \text{dm}^{-3}$ (Appelo, Willemsen, 1987).

Results

On the basis of the obtained results, a high diversity in chloride concentrations in particular objects can be observed. In the waters of the Martwa Wisła a considerable difference is observed between particular measurement sites. The results obtained from all the sites ranged from 73 to $3880 \text{ mgCl} \cdot \text{dm}^{-3}$. In sites located the closest to both outlets into the sea (the river has two), the mean chloride values were $2860 \text{ mgCl} \cdot \text{dm}^{-3}$, which is close to 70% of the value obtained for the Gulf of Gdańsk ($4126 \text{ mgCl} \cdot \text{dm}^{-3}$), while in the remaining measurement sites the mean value was $2181 \text{ mgCl} \cdot \text{dm}^{-3}$. Especially interesting is the measurement site in Przegalina, where concentrations ranged from $73 \text{ mgCl} \cdot \text{dm}^{-3}$ (fresh water) to $2800 \text{ mgCl} \cdot \text{dm}^{-3}$ (brackish water).

In the case of the rivers Łupawa and Łeba, constantly elevated values of chloride concentrations are observed. The mean values of chlorides in the whole study period for the Łeba ranged from $1632 \text{ mgCl} \cdot \text{dm}^{-3}$ in the town of Łeba to $1688 \text{ mgCl} \cdot \text{dm}^{-3}$ in the mouth section, while for the Łupawa $1397 \text{ mgCl} \cdot \text{dm}^{-3}$ in the mouth section. The results obtained for the Łeba ranged from 811 to $2215 \text{ mgCl} \cdot \text{dm}^{-3}$. Thus, continuous penetration of salt waters in this canal can be identified here. In the River Łupawa the extreme values ranged from as little as $78 \text{ mgCl} \cdot \text{dm}^{-3}$ up to even $4161 \text{ mgCl} \cdot \text{dm}^{-3}$ (Figure 2). Only in one case the value reached just $78 \text{ mgCl} \cdot \text{dm}^{-3}$ (stronger impact of the River Łupawa), while in the remaining ones it did not fall below $250 \text{ mgCl} \cdot \text{dm}^{-3}$.

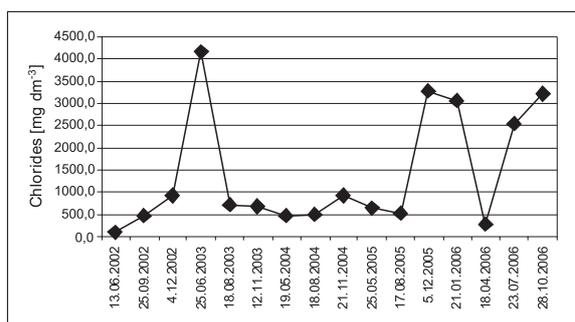


Figure 2. Chloride concentrations in the mouth section of the Łupawa Channel in the years 2002–2007

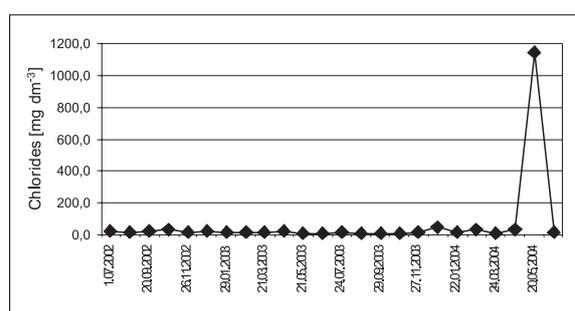


Figure 3. Chloride concentrations in the mouth section of the River Reda in the years 2002–2004

attributed not only to the greater distance from the sea but also the influence of the very lake and the main tributary of the river – Główny Rów, where the mean chloride concentrations were at a level of 68 mgCl·dm⁻³. The range of the obtained results was from 424 to 3650 mgCl·dm⁻³ in the mouth section and from 68 to 485 mgCl·dm⁻³ at the second site.

Conclusion

The rivers selected for the analysis, despite the same location, have different features distinguishing them from each other. An example of such differences is the occurrence or lack of the phenomenon of intrusions and its qualitative effects on particular objects. Despite considerable differences, however it is possible to notice a constant tendency in all the analysed rivers, i.e. an increase in chlorides content towards the sea shoreline. The most frequent and most intense impact of the Baltic Sea is observed in short sections of the rivers which additionally have a hydrological connection with large coastal lakes (Łeba, Łupawa). The obtained results indicate that the River Łeba is under continuous and strong impact of the sea, while the River Łupawa can undergo situations when this impact is slight, but very strong intrusions can occur as well resulting in chloride values close to those observed in the sea. Similar is the case with the rivers Potynia and Głownica, though the intensity of the impact is not as high as in the previous two cases. Lower salinity values should be attributed mainly to the local hydrographic conditions. Similar would be the case of the Piaśnica but nowadays, due to the operation of the water power station in Żarnowiec, the phenomenon of intrusions does not occur. On the other hand, in the River Reda the phenomenon of salt waters intrusion was recorded only once in the whole study period. The scarcity of periods with observed intrusion is probably related to strong discharges in the river during the whole year, the delta, formed in the mouth, limiting free flow of salt waters up the river and a lack of access of open sea waters (the river discharges into the Puck Bay). In the waters of the Płutnica the phenomenon of intrusions was not observed at all, which is probably due to man's activity, which since

In the case of the rivers Piaśnica and Płutnica there are no symptoms of brackish waters intrusions. The mean chlorides' values in the waters of the Piaśnica ranged from 25.5 mgCl·dm⁻³ at the very outflow from Lake Żarnowieckie to 35.2 mgCl·dm⁻³ at the outlet to the sea. The extreme values ranged from 19.9 to 40.1 mgCl·dm⁻³. The mean chloride concentration in the River Płutnica was 31.5 mgCl·dm⁻³, and the extreme values ranged from 14.5 to 58 mgCl·dm⁻³.

The mean chloride values in the River Reda ranged from 12.8 mgCl·dm⁻³ at the site located about 1 km from the mouth to 65.1 mgCl·dm⁻³ at the very mouth. The obtained values ranged from 9.6 to 1143 mgCl·dm⁻³ in the mouth (Figure 3). The reason for such a high, though incidental (over 1100 mgCl·dm⁻³) concentration, unnatural with regard to the remaining dates, was the intrusion of brackish waters, caused by very strong winds (over 10 m·s⁻¹) from the eastern sector lasting for several days preceding the measurement.

The waters of the River Potynia were characterised by elevated chloride concentrations. The mean for the whole study period was 224 mgCl·dm⁻³, while the range of results was from 37 to 860 mgCl·dm⁻³. The waters of the River Głownica, however, reached the mean value of chlorides of 1427 mgCl·dm⁻³ in the mouth section and 200 mgCl·dm⁻³ just after leaving the lake. Such a low value at the second site, in comparison to the first one, should be

the 20th century has heavily transformed the water relationships not only in the mouth section. The last analysed river is the Martwa Wisła, which has a constantly elevated salinity, often close to that of sea water. This should be attributed to a lack of discharge in the river (stagnant water), numerous connections with the Gulf of Gdańsk and a scarce inflow of fresh waters from the catchment.

References

- Appelo C.A.J., Willemsen A., 1987: *Geochemical calculations and observations on salt water intrusions, a combined geochemical/mixing cell model*. Journal of Hydrology, 94: 313-330.
- Crisci A., Gozzini B., Meneguzzo F., Pagliara S., Maracchi G., 2002: *Extreme rainfall in a changing climate: regional analysis and hydrological implications in Tuscany*. Hydrological Processes, 16(6): 1261 – 1274.
- Cyberski J., 2003: *Flood in Gdańsk 2001*. Wyd. GTN, Gdańsk (in Polish).
- Giambastiani B.M.S., Antonellini M., Gualbert H.P., Essink O., Stuurman R.J., 2007: *Saltwater intrusion in the unconfined coastal aquifer of Ravenna (Italy): A numerical model*. Journal of Hydrology, 340(1-2).
- Van der Thuin H. (ed.), 1990: *Guidelines on the study of seawater intrusion into rivers*. International Hydrological Programme, UNESCO, Paris.