Summary

Dynamic industrial development and improper waste management contribute to the increased influx of pollutants into surface waters. Heavy metals and xenobiotics are particularly significant. They enter aquatic ecosystems primarily through municipal and industrial wastewater discharges, as well as through intensive urbanization, agricultural, and industrial activities. These substances pose a serious threat because they are characterized by very low susceptibility to degradation and, moreover, have the ability to accumulate in the environment. Therefore, the presence of heavy metals and xenobiotic compounds such as polycyclic aromatic hydrocarbons (PAHs), pesticides, and pharmaceuticals in water poses a persistent risk to aquatic organisms, which in turn emphasizes the need for constant monitoring of the scale of pollution and its potential consequences.

The Baltic Sea drainage basin covers an area four times larger than the sea itself and is inhabited by approximately 85 million people. This spatial arrangement makes the sea particularly susceptible to the inflow and accumulation of toxic substances. One of the key pathways through which pollutants – including heavy metals – enter the Baltic Sea is river runoff, including the Vistula and Oder rivers. The management of these river basins and the presence of numerous point sources in their sub-basins not only impact water quality but also directly shape the state of the marine environment. Therefore, it is essential to conduct activities aimed at identifying toxic compounds in the ecosystem, analyzing their transfer and transformation pathways, assessing their impact on various levels of the trophic chain, and determining their potential toxicity.

This doctoral dissertation presents the results of field and laboratory studies, as well as analyses conducted on the contamination of aquatic ecosystems with xenobiotics and heavy metals. The scope of the work included: i) assessing the degree of pollution of the Baltic Sea with heavy metals originating from its catchment area, ii) analyzing the contribution of Polish rivers to the transport of these compounds to the Baltic Sea, and iii) determining the impact of point sources: municipal wastewater treatment plants and industrial plants, on the water quality of the Pilica River (the largest left-bank tributary of the Vistula), in terms of the presence of heavy metals and PAHs belonging to the xenobiotic group.

The results of the analyses shed new light on the contribution of individual Baltic countries to the influx of heavy metals into the Baltic Sea and enabled grouping of these countries based on similarities in emission sources and metal transport mechanisms. Furthermore, the research helped fill gaps in knowledge regarding the contribution of Polish rivers – the Vistula, Oder, and Polish Coastal Rivers – to the long-term influx of heavy metals into the Baltic Sea. Furthermore, using a top-down approach, it enabled the identification of wastewater treatment plants and industrial plants as sources contributing to surface water pollution with both heavy metals and PAHs. Furthermore, the study conducted a holistic analysis of current standards for maintaining surface waters in good condition, as well as the latest data on effective methods for eliminating pollutants from the environment using low-cost, environmentally friendly methods such as Nature-Based Solutions and ecohydrological biotechnologies. The results of the study indicate that only an integrated approach to eliminating pollutants within individual catchments offers a real chance of improving surface water quality and reducing pollution in the Baltic Sea.