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The influence of cold season warming on the mercury pool in coastal benthic organisms

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ABSTRACT

One of the tendencies for climate changes in the southern Baltic region is towards the warming of the cold season (late autumn, winter, early spring), which leads to the disappearance of icing even in the coastal zone and affects the fluxes of chemicals in the surface sediments of the coastal zone. This will lengthen the period in which the deposited chemicals may become remobilized from the sediments into pore and near-bottom water. Studies into the mercury concentration in macrophyto- and macrozoobenthos were conducted at two stations in the coastal zone of the southern Baltic, in the Puck Lagoon, from January 2012 to May 2013. It was estimated that the mean annual Hg pool (mass of Hg in flora or fauna per m^{-2} of sediments) in macrophytobenthos in a year without icing was higher by 30%, and in macrozoobenthos by 25%, compared to an estimated previous year in which the icing period lasted approximately 90 days (as was usual in the period between 1946 and 1991). Taking into account the combined total mass of flora and fauna, it was estimated that lack of icing on the lagoon increases the mean Hg pool in benthic organisms (macrophyto- and macrozoobenthos) by 30%, which in turn considerably increases the Hg load on the first levels of the trophic chain despite a decrease in Hg emissions. The warming of the cold season has a particular influence in areas where macroalgae species are predominant in the biomass over angiosperms. Of the zoobenthic taxa, *Corophium*spp. exhibited a tendency for intense growth and Hg accumulation in late autumn.

1. Introduction

Mercury (Hg) has been recognized as one of the most dangerous pollutants, being neuro-, nephro-, and immunotoxic (Bose-O'Reilly et al., 2010). It can cause kidney damage and can cross the blood–brain barrier, resulting in neurological damage (Langford and Ferner, 1999). There is no known safe level of exposure but, ideally, humans should have no mercury in their bodies at all (Bose-O'Reilly et al., 2010). The main route of Hg penetration into the human body is the consumption of fish and seafood (Li et al., 2010), and the presence of this metal in the marine environment is therefore an important problem. Due to the fact that mercury inflow comes both from the atmosphere and from land (with surface run-off and via rivers) coastal zones of estuaries or shallow bays are particularly exposed to the presence of Hg. This is of particular importance owing to the fact that such areas tend to be used commercially for fishing or seafood collection, or for the development of aquaculture.

Through the reduction of industrial metal emissions and the modernization of water purification plants, Hg discharge into the southern Baltic has decreased (HELCOM, 2010). In the past, however, the inflow of Hg to this region was intensive (Wrembel, 1997) and, for that reason, its concentration in sediments exceeds the natural levels of this element (Bełdowski and Pempkowiak, 2003). The dangers related to the presence of Hg in sediments depend on the form in which this metal is found therein. An analysis of Hg speciation in surface sediments of the southern Baltic, depending on the type of sediment and conditions above the sediment, showed that the percentage share of the mobile Hg fraction was between a few and 60% (Bełdowski and Pempkowiak, 2007). Its speciation may be further modified in coastal sediments, due to oxygen consumption by decaying organic matter, icing conditions or the input of fresh organic matter from primary production. This may lead to complex changes in bioavailability throughout the year,

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and is closely connected to climate change and related meteorological conditions (Bełdowski and Pempkowiak, 2007).

One of the significant ways in which Hg becomes remobilized from sediments and included in the trophic chain is its absorption by benthic organisms. The improvement in the quality of the marine environment in the southern Baltic, particularly in the Puck Lagoon, is conducive to the growth of phytobenthos (Kruk-Dowigałło, 1991; Gic-Grusza et al., 2009; Osowieck et al., 2009; Saniewski, 2013), and the growth of plant organisms in turn creates favorable conditions for the development of zoobenthos (Włodarska-Kowaliczuk et al., 2014). Intense growth of these benthic organisms is further influenced and supported indirectly by a lack of icing in the winter season.

One of the tendencies for climate changes in the southern Baltic is towards the warming of the cold season (late autumn, winter, early spring) (Kożuchowski, 2009; HELCOM, 2013; IMGW PIB, 2015). Warmer winters result in a lack of icing or its persistence for a shorter period of time, thus giving benthic organisms better conditions for survival and growth, and resulting in the extension of the time during which Hg is actively absorbed from sediments. The main aim of the present paper was to estimate the influence of the warming of the cold season on the Hg pool in phyto- and zoobenthos, in the coastal zone of a boreal environment. The studies were conducted at two stations in the Puck Lagoon, taking into account the species composition of benthic organisms.

2. Materials and methods

The samples were collected monthly from January 2012 to May 2013, at 2 coastal stations: Chałupy and Osłonino (Fig. 1). In February 2012 (both stations), December 2012–February 2013 at Chałupy station and January–March 2013 at Oslonino station samples were not collected because of ice cover. Both Chałupy and Osłonino are located in the Puck Lagoon, where the average depth is 3 m, and the stations were located in a shallow part of the bay with a mean depth of 0.5 m (Nowacki, 1993). In the second half of the 20th century many pollutants, including mercury, were deposited in the study area – the interior, sheltered part of the Puck Lagoon which has limited water exchange, prolonging the residence of pollutants (Wrembel, 1997; Kannan and Falandysz, 1998). The shallow depth, on the other hand, is conducive to the growth of benthic organisms as well as to the remobilization of chemicals. This is significant, as in the last few years the quality of the Puck Lagoon has greatly improved, which contributes to an increase in the population of marine organisms, including fish often consumed by humans (Kruk-Dowgiallo, 1991; Gic-Grusza et al., 2009). The stations selected for the study are located away from anthropogenic sources and in an area of little interest to tourists. The Osłonino station is situated in direct vicinity of the shore, while the Chałupy station is on the other side of the lagoon, close to the narrow Hel Peninsula.

Fig. 1. Map of the study area.

Samples were collected about 10 m from the coastline using a manual Van Veen grab sampler with a grab area of 250 cm^2 in three repeats. In order to separate the benthic organisms, samples of marine sediments were sieved through a 0.5 mm mesh. Live biological material was placed in containers with sea water *in situ* and transported to the laboratory. All samples were kept aerated until the period of biological analysis.

2.1. Biological analyses

2.1.1. Macrophytobenthos

Macrobenthic algae and angiosperms were identified to the highest possible taxonomic separation within two days of collection using the taxonomic keys of Bernatowicz and Wolny (1969) and Braune and Guiry (2011). Nomenclature followed Algae Base (http://www.algaebase.org) and the European Register of Marine Species (ERMS, http://www.marbef.org/data/erms.php). All representatives of identified taxa were dried to determine their biomass (g m^{-2}).

2.1.2. Zoobenthos

Organisms were counted and categorized according to the species or a higher systemic unit, using a stereoscopic microscope. Crustaceans: *Gammarus spp., Idotea spp., Corophium spp.*, and *Jaera spp.*, and snails: *Hydrobia spp.*, were identified to genus. All insect larvae were classed as one group – *Insecta larvae*. The taxonomic identification of organisms was carried out on the basis of their observed morphological traits and the available taxonomic keys (Barnes, 1995; Żmudziński, 1990). In the quantitative analysis, each of the aforementioned groups was treated as a separate taxon. The analysis of benthic macrofauna was carried out according to current standards of laboratory procedures for the processing of biological samples used in the international monitoring of the Baltic Sea (HELCOM, 1988). Classification to the taxonomic ranks and nomenclature followed the European Register of Marine Species (ERMS) (Costello et al., 2001). To determine the biomass (g m^{-2}) organisms were dried.

2.2. Chemical analyses of Hg

The taxonomically segregated biological material was placed in etched and weighed containers. In the case of the *Hydrobia* spp., *Lymnea*, *Theodoxus*, *Mya arenaria*, *Cerastoderma glaucum*, *Mythilys edulis*, *Macoma balthica*, only soft tissue was analyzed. All samples were preserved at −20 °C until the time of chemical analysis and were freeze-dried prior to analysis. Determination of Hg concentration was carried out using an AMA 254 advanced mercury