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Impact of intense rains and flooding on mercury riverine input to the coastal zone

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ABSTRACT

The aim of the present research was to determine the impact of intense rains and flooding on mercury riverine input to the coastal zone. This study focused on four small rivers (Reda, Zagórska Struga, Płutnica, Gizdepka), typical of the Southern Baltic region, with no significant mercury sources. Samples were collected for 16 months during average flow conditions and during selected meteorological events: floods, downpours, thaws and droughts. Results showed decreased retention of mercury during intense rainfalls, thus demonstrating mercury elution from the catchment. Floods and melting snow also have a tremendous impact on the outflow of mercury from the catchment. Development of urban infrastructure and farmlands increases the outflow of mercury from the catchment too, making such areas a significant source of mercury in the river. On the other hand, areas with natural character, predominated by forests, stimulate retention of mercury that reaches them through dry and wet atmospheric deposition.

1. Introduction

On a global scale, the main route of mercury transportation between land and the ocean is the atmosphere, while the mercury load introduced into the sea via rivers is relatively small. However, in coastal areas, rivers are the main component of Hg circulation (HELCOM, 2010; Saniewska et al., 2010; Saniewska, 2013). Mercury of riverine origin mostly accumulates in the coastal zone and in the waters close to river outlets (Cossa and Martin, 1991; Laurier et al., 2003; Jędruch et al., 2017). This result in the concentrations of mercury in the coastal zone being many times higher than those measured in the open waters of the sea (Mason et al., 1998; Horvat et al., 2003; Saniewska et al., 2010). This is also reflected in the increase of Hg concentration in sediments (Jędruch et al., 2015) as well as in macrophytobenthic (Bełdowska et al., 2016). This problem is of particular importance in areas where there is a high ratio of catchment area to the surface of the basin itself (Balcom et al., 2004). This is clearly visible in the Baltic Sea. The fact that the area of the Baltic Sea is four times smaller than its catchment area results in a situation wherein 86% of the Hg introduced to the sea is of riverine origin (Knuuttila, 2009; Saniewska, 2013; Bełdowska et al., 2014).

A river and its catchment is a very complex system, so it is difficult to single out one major factor responsible for the circulation of mercury in this environment. Each particular river can be different in many respects: geological structure, type of soil, land use, or the size of its catchment. All these different factors have a strong influence on the level of mercury in the river and Hg outflow to the sea (Hurley et al., 1995). Hydrological conditions (i.e. floods, droughts and thaws) are also an important factor controlling the transport of mercury in the river (Mason and Sullivian, 1998; Han et al., 2006; Saniewska et al., 2014c; Bełdowska et al., 2014). Determining the impact of hydrological conditions on Hg transformations in river systems is of particular importance in the context of current climate changes, which translate into changes in the hydrological cycle resulting in floodings. The forecasts of climate change in the Southern Baltic anticipate an increase in total annual precipitation as well as an increase in the intensity and frequency of extreme precipitation and floods (Kundzewicz and Matczak, 2012; HELCOM, 2013). Hence the aim of the present study was to estimate the role of extreme precipitation and floods on mercury outflow into the Southern Baltic from various types of catchments (forests, farmlands, meadows, pastures, urban areas).

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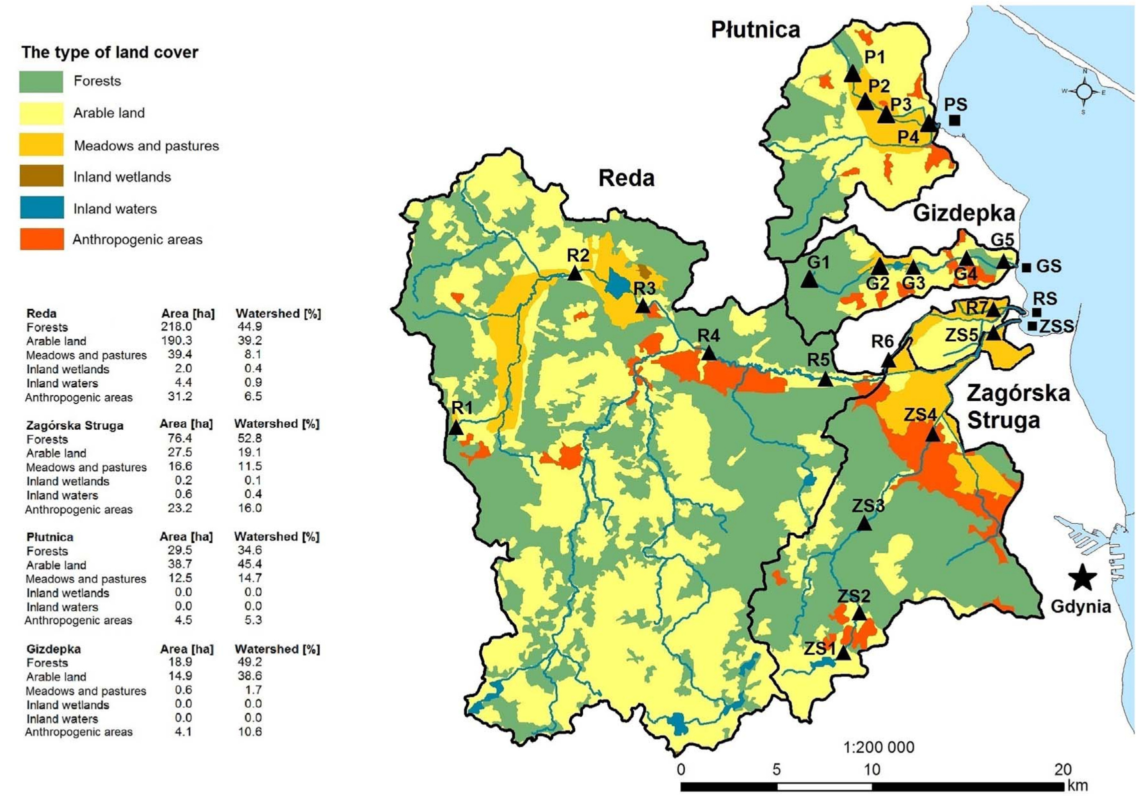

Fig. 1. The locations of the sampling stations.

2. Materials and methods

2.1. Study area

The study was conducted in the Southern Baltic region. Water samples for mercury analysis were collected from four rivers: the Reda, the Zagórska Struga, the Płutnica and the Gizdepka in northern Poland (Fig. 1). All of these rivers flow into the Puck Bay. Land usage in the catchment area of the Puck Bay is typical for the Southern Baltic region (Pastuszak and Igras, 2012). The sampling stations were designated on each river to represent the most common types of land use in the catchment area: forests, cultivated fields, meadows and pastures, wetlands, and urban areas (Fig. 1).

The **Reda** has the largest catchment area, length and water flow among the studied rivers (Table 1). Seven stations were designated on the Reda: R1 - at the source of the river, R2 - before an artificial lake and R3 - beyond the lake, R4 before the town of Wejherowo (47,323 inhabitants in 2015), R5 - between Wejherowo and the town of Reda (23,268 inhabitants in 2015), R6 - beyond Reda, and R7–1000 m from the river outlet into the Puck Bay (Fig. 1).

Among the studied rivers, the **Zagórska Struga** is the second largest river in terms of the catchment area (Table 1). There were five stations: ZS1 - source, ZS2 - before a forest, ZS3 - beyond the forest and before the town of Rumia (47,812 inhabitants in 2015), ZS4 - beyond Rumia, ZS5–800 m away from the river outlet into sea (Fig. 1).

Another of the studied rivers was the **Płutnica**. It had four stations: P1 - source, P2 - station before a gravel pit and P3 - beyond it, P4–400 m away from the river outlet into the Puck Bay (Fig. 1).

The last studied river was the **Gizdepka**. This river has the smallest catchment area and the lowest flow out of the studied water courses (Table 1). However, the diversity of its catchment area led to the designation of five stations: G1 - source, G2 - station before a pond and G3 - beyond it, G4 - beyond the village of Żelistrzewo (2649 inhabitants in 2015), G5–600 m away from the river outlet into the sea (Fig. 1).

In addition, water was collected from the Puck Bay coastal zone in the vicinity of the mouths of the studied rivers (about 200 m from the outlets: RS, ZSS, PS and GS stations) (Fig. 1).

Precipitation samples were collected in parallel at the coastal station situated on the roof of the University of Gdansk Institute of Oceanography in Gdynia (54°30’34”N, 18°32’28″E) (Fig. 1). Operating at a height of 20 m above ground level enabled measurements to be conducted above nearby treetops and buildings. The Institute of Oceanography building is located around 800 m from the sea, in an urbanized area in the vicinity of major roads. A detailed description of the stations is to be found in publications by Bełdowska et al. (2012) and Saniewska et al. (2014a). The collection at the coastal station allowed us to estimate the amount of mercury that enters the land with atmospheric deposition. This information made it possible to estimate the retention of atmospheric Hg in land and the outflow of Hg from the catchment basins.

Table 1
Characterization of the studied rivers.

River	River length[a]	Catchment area[a]	Average flow[a] (1951–1983)	Average flow during the study period (IV 2015-VII 2016)
	km	km^2	$m^3 s^{-1}$	$m^3 s^{-1}$
Reda[b]	44.9	485.2	4.2	5.9
Zagórska Struga	26.0	144.5	0.6	1.5
Płutnica	11.2	85.2	0.7	0.8
Gizdepka	11.8	38.5	0.2	0.3

[a] Korzeniewski, 1993.
[b] Flow measured in various places - multiannual flow given for station R4, flow in the study period given for station R7.