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Heavy Metals Assessment in Water Reservoirs Reinforced By Służewiecki Stream

Małgorzata Wojtkowska[1], Ewa Karwowska[1], Iwona Chmielewska[1], Krzysztof Wawer[1]

[1]*Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology, Warsaw, Poland*

ABSTRACT
The study concerned copper and cadmium contamination in bottom sediments of selected surface water reservoirs at the urban area. The concentrations of the metals in sediments was up to 20-times higher compared with a geochemical background. Based on ecotoxicological evaluations, the toxic impact of cadmium in tested sediments can occur frequently, while for copper – it can sometimes be observed. The sediments can be classified as heavily polluted and dangerous to water biota, especially for sediment-dwelling organisms. The accumulation of metals migrating with the Służewiecki stream in reinforced reservoirs can result in their anthropopressure- related degradation.

Keywords: copper; cadmium; water reservoirs; bottom sediments; ecotoxicological evaluation

I. INTRODUCTION

The massive pollution of surface waters caused by the household and industrial sources is a serious problem nowadays. The contaminants enter the water environment from the air, sewage systems and with the surface runoff; some of them are discharged intentionally as a kind of the temporary solution of a local wastewater management. They include numerous compounds, i.e. heavy metals, petroleum derivatives, organic compounds, feces and pathogenic microorganisms which can enter surface water reservoirs [1, 2]. It results in improper functioning of water ecosystems, a decrease in water self-purification process and the subsequent degradation of water reservoirs.

The chemical pollutants present in bottom sediments can negatively influence not only the organisms inhabiting the reservoir but also the potential users – animals and people. The compounds can be released from sediments in particular conditions (pH, red-ox potential, temperature, salinity), causing the secondary pollution of water. The presence of heavy metals in bottom sediments should be especially considered due to their ability to accumulate in tissues and potential toxicity.

Most of the research on the bottom sediments contamination with heavy metals focuses on the industrial areas. There is still few information concerning the metals' behavior in sediments of water reservoirs located in urban areas, with a quite different type of an anthropopressure [3]. The surface waters monitoring in Warsaw, Poland revealed the problem of anthropogenic pollution, including the excessive concentrations of heavy metals in bottom sediments of some reservoirs [4].

In this study an evaluation of copper and cadmium pollution of water reservoirs reinforced by Służewiecki Stream, Warsaw, Poland was accomplished based on the analyses of bottom sediments.

II. MATERIAL AND METHODS

Tested water reservoirs

The samples of bottom sediments were taken from the Służewiecki Stream, Upper Beręsewicz Pond, Lower Beręsewicz Pond and Wyścigi Pond in Warsaw.

S □u □ewiecki Stream

Służewiecki Stream is a watercourse located partly in the old riverbed of Sadurka River with the catchment size of 54,8 km^2. It starts and ends as an open brook, but partially it is covered in a pipeline. The stream flows through the Wyścigi Pond and it reinforces the Beręsewicz Ponds (Upper and Lower) by means of a detour system [5]. For many years the stream was used as a natural drainage for the surrounding area. As a result of an urbanization process (especially the construction of the nearby airport), the stream was regulated and adapted to the increased surface runoff (mainly rain water transport). At the moment the stream receives the urban runoff from the surrounding streets and the airport area, which is only partially treated. Moreover, the stream is

probably contaminated by uncontrolled discharge of the wastewater of a domestic or industrial origin. Beręsewicz Ponds The Beręsewicz Ponds system consists of two parts - Upper and Lower pond, located on a total area of 11900 m^2, characterized by the retention volume of 11400 m^3 (Figure1). They serve as the reservoirs for the excess water of Służewiecki Stream during the spate, preventing the flood danger in the neighbouring areas. For the lower water conditions in the Służewiecki Stream, the water flow through the Beręsewicz Ponds is very low. The water damming point is located between the Służewiecki Stream and the Upper Beręsewicz Pond. In 2004 the ponds were revitalized. It was revealed that a bowl of a pond contains the grounds of the anthropogenic origin (sands, clays, humus, and a brick rubble) as well as organic, alluvial and sandy-glacial soils [6].

Fig.1. Beręsewicz Pond

Wy cigi Pond

Wyścigi Pond (Figure 2) is a flow reservoir characterized by a retention volume of about 17671 m^3. In 2006 the pond was rebuilt (within the existing pond bowl) to restore the retention and landscaping qualities. The excavated bottom sediments were landfilled in heaps located in the nearby area.

Fig. 2. Wyścigi Pond

Sampling and analytical methods

The 250 cm^3 samples were taken from the bottom sediments of the ponds (Upper and Lower Beręsewicz Pond and Wyścigi Pond) as well as the bottom sediments from Służewiecki Stream, in 2009, 2010 and 2011. A sample of a soil (with fragments of plants) collected from the area located several hundred meters from the sampling area was used as a control (geochemical background). Copper and cadmium concentration in sediments was performed applying atomic absorption spectrometry (AAS) with flame atomization. The samples of sediments were dried at room temperature to constant weight. Total metal concentrations in samples were determined by means of total extraction with HNO_3 and $HClO_4$ (1:3) in a Teflon bomb. The same procedure without samples was used as a control. Metals were analyzed using flame atomic absorption spectroscopy (F-AAS) type Philips PU9100. Three measurements were conducted for each sample. Quality assurance and quality control (QA/QC) for metals in sediment samples were estimated by determining metal concentrations in the Merck Standard solutions (Merck, Darmstadt, Germany). Blank determinations were carried out for each analysis batch. A reference sediment samples (BCR 701 Lake Sediment) was analyzed to determine the accuracy of the analysis. The detection limit was calculated based on the estimated instrumental detection limit assuming that 1 g of a sample is digested or diluted to 100 mL. Detection limits (mg/kg of dry matter) for Cu and Cd were: 0.003 and 0.001, respectively. The precision of the analytical procedures was calculated relative standard deviation (RSD) and ranged from 5-10%.It was calculated based on the standard deviation divided by the mean. Investigated metals rates of recover were 90 ± 10%. Chemicals, Solutions and reagents were of analytical grade. All glassware before use was washed with distilled water, rinsed in nitric acid (30%), and then washed with deionized water and air dried.

The results were interpreted in relation to the standards of sediments quality of Polish law [7] and compared with ecotoxicological threshold values [8]:

- TEL (Threshold Effect Level - which represents the concentration below the adverse effects would be rarely observed).
- PEL (Probable Effects Levels – representing the concentration above which adverse effects are expected to occur frequently)
- TET (Toxic Effect Threshold - determining the heavy sediment pollution)
- SEL (Severe Effect Level – representing the concentration above which the negative effects in the majority of sediment-dwelling organisms are observed)

III. RESULTS AND DISCUSSION

It was determined that copper and cadmium concentrations in bottom sediments of tested water reservoirs were several times higher than their content in the sample used as a geochemical background for the area (Fig. 3 and Fig 4). Compared with a threshold values for the contaminated bottom sediments excavated form water reservoirs (according to Polish law), the copper content was too high in sediments taken from Wyścigi Pond, while for cadmium all in all samples of sediments the threshold value was exceeded.

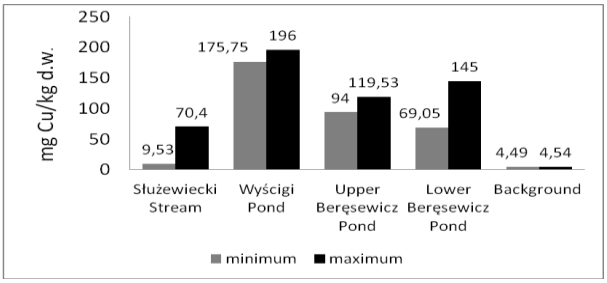

Fig. 3. Copper content in bottom sediments

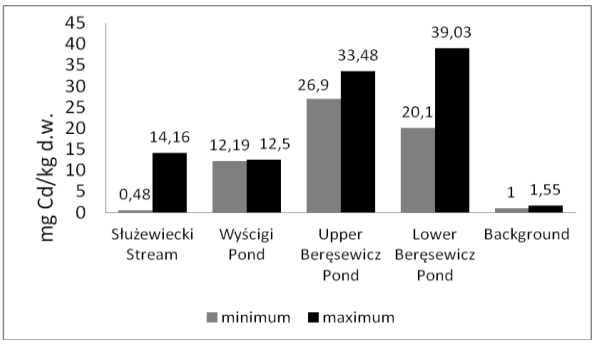

Fig. 4. Cadmium content in bottom sediments

Heavy metals concentrations in bottom sediments were even 20-times higher than in the sample representing the geochemical background, therefore based on the geochemical criteria [9, 10] they can be classified as belonging to the III class (contaminated sediments).

The ecotoxicological evaluation of the sediments confirmed their significant contamination.

The PEL values for copper and cadmium, given in the literature, are 197 mg/kg and 3.53 mg/kg respectively [8]. Thus, the concentration of cadmium in all the samples taken from the water reservoirs reinforced by Służewiecki Stream exceeded PEL threshold value for this metal. According to this, the toxic impact of Cd on living organisms can be frequently observed in tested bottom sediments.

The TEL values are 35.7 mg/kg for copper and 0.596 mg/kg for cadmium [8], so copper concentrations in tested samples exceeded the TEL threshold value. It allowed to conclude that in tested bottom sediments the toxic influence of copper can sometimes be observed.

Comparing the results of sediment analyses with TET and SEL values, which are: for copper – 86 mg/kg and 110 mg/kg, respectively and for cadmium – 3 mg/kg and 10 mg/kg respectively [8] it can be stated that the sediments can be classified as heavily polluted and dangerous to the water biocenosis, especially in case of sediment-dwelling organisms. The ecological risk of the presence of Cd and Cu in sediments was reported previously by Liu et al.[11]. Yang et al. [12] considered the high bioavailability of Cd and Cu in sediments which increased the ecological risk.

Honglei et al. [13] revealed that in sediments of Moshui Lake the copper contents were 11-times higher compared with SEL value resulting in high risk potential. The authors pointed out the influence of urbanization on heavy metal contamination of water reservoirs. The strong differences in Cu and Cd concentrations in lake sediments between rural and urban areas were observed also by Kische and Machiwa [14].

The concentrations of Cu and Cd in reservoirs sediments were higher compared with their content in the sediment taken from Służewiecki Stream which confirmed their intensified accumulation in lentic waters. The average concentrations of Cu and Cd in the Stream were about 28 mg/kg and 2.3 mg/kg respectively with showed 5-times accumulation of copper and 5-15-times accumulation of cadmium in ponds sediments.

IV. CONCLUSIONS

The above results show that Służewiecki Stream and the accompanying reservoirs Wyścigi Pond and Beręsewicz Ponds are highly degraded because of the heavy metals pollution (especially Cd), which reflects the strong anthropopressure. The metals migrate with the water of Służewiecki Stream and accumulate in sediments of the reinforced reservoirs. It should be pointed out, that in case of the change of physical-chemical conditions (pH, temperature, CO_2 content) in tested reservoirs, the re-emission of pollutants from bottom sediments is possible. It can cause a rapid and strong contamination of waters of the Służewiecki Stream downstream from the tested reservoirs resulting in the real threat to the biota.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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