



Distribution and ecological risk assessment of organic and inorganic pollutants in the sediments of the transnational Begej canal (Serbia-Romania)[☆]

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ABSTRACT

This research is designed to determine the level and types of pollution in the highly contaminated sediments of the international Begej canal in Timiș district, Romania and north-eastern Serbia. The cross-border canal stretch investigated is currently not navigable, but represents an important waterway between the Danube River in Serbia and the city of Timisoara. Surface sediments were monitored annually from 2008 to 2016 at 36 representative sampling locations, with a wide range of analyses, including eight heavy metals of long-term monitoring concern (Ni, Zn, Cd, Cr, Cu, Pb, As and Hg) and the 16 USEPA PAHs. The purpose of this study was to determine the diversity and impact of anthropogenic and natural sources of pollution at the pollution hot spots on the canal: at the Itebej lock (near the border with Romania) and downstream at the Klek lock.

Sediment quality and ecological risk were assessed in order to determine pollutants of concern. Several multi-proxies were applied (e.g. geo-accumulation index (I_{geo}), ecological risk index (RI) and total benzo[a]pyrene equivalent ($B[a]P_{eq}$)). To determine and predict trends, multivariate statistical methods (factor analysis of principal component analysis (PCA/FA)) were carried out on the organic and inorganic parameters analysed.

In the near-border region, acute and significant ecological impacts were observed. The heavy metals Hg, Cr, Pb, Cu and Zn, and the carcinogenic PAH dibenzo[a,h]anthracene, were historically the most frequently detected harmful substances to biota in this and the wider Pannonia region. This is the first long-term study to quantify and derivate the most frequently detected harmful substances of concern for this and similar sites in the wider region, and is additionally supported by significant national and similar environmental data from previous studies in the region.

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1. Introduction

The Begej canal is an artificial canal that flows as an extension of the Begej river from Temisvar, Romania to its confluence in the Tisa river downstream from Zrenjanin. In Romania, the Begej river is 45 km long, and the canal is around 76 km long in Serbia. In previous years, the Begej canal was an important transnational

navigable route between the Danube River in the north-eastern part of Serbia and the city of Temisvar. At the beginning of the 20th century, when hydroelectric complexes at Itebej (north-east Serbia, on border with Romania) and Klek (on the southern side) were built on the canal, the accompanying shipping locks created a significant navigable waterway allowing the passage of 500 t capacity ships. For political and economic reasons, navigation of the canal was suspended in 1958 on the Yugoslav-Romanian border. After the closure to navigation, sediment accumulated rapidly and an increase in sediment and water contamination began. Nowadays, Itebej lock is still closed to shipping. A large amount of the sediment has therefore accumulated upstream and downstream of

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the Itebej lock, as well as upstream from the Klek lock. It is estimated that from the border with Romania to the DTD channel at Klek, 415 000 m³ of sediment has been accumulated thus far. The Begej canal is currently a recipient of wastewater and run-off from the surrounding agricultural land during periods of heavy rain. The canal water bears significant amounts of sediment, which begins to settle as the stream slows down in the canal. The amount of sediment depends on the amount of precipitation and erosion. The sedimentation is clearly visible by the banks of the canal, where the depth of the canal is reduced and the growth of plants further slows down the flow. As a result of the inflow of industrial and municipal waste waters from the city of Temisvar and downstream settlements in Romania (Dalmacija et al., 2006; Beilicci and Beilicci, 2012) the quality of sediments in the canal in Serbia are highly contaminated near the border.

In the Serbian part of the canal, there is a limited inflow of anthropogenic and natural sediment into the canal. Flow velocities in the canal are low enough for sedimentation, with the depth of the canal now too small for navigation. Currently, the maximum allowed flow through the canal is 83.5 m³/s, and the minimum is maintained at 5 m³/s. The maximum flow was formally established by a joint agreement between Yugoslavia and Romania from 1995. The average flow rate is between 10 and 25 m³/s. During the research period, groundwater levels were measured several times. Measured levels moved along the slope at 80.5–81 m, with the levels at the beginning around 80 m. Oscillations in the groundwater level in this period were very low, such that no useful correlation can be made between the investigated parameters and the minimum and maximum groundwater levels. The groundwater levels in the immediate vicinity of Begej are however directly related to the water level in the Canal (ISPA information sheet, 2000, RO 16 P PE 004).

In this research, between 2008 and 2016, a wide variety of pollutants were monitored in the canal and compared to the national legislation values (RS 50/2012, 2012) and European Union Directive 2013/39/EU (EC, 2013) recommendations. Several studies report similar distributions and increased levels of priority substances and other contaminants in nearby locations (Dalmacija et al., 2006; Prica et al., 2008; ICPDR, 2000). Several key organic and inorganic ecological and toxicity proxies were used in order to quantify the level and spatial distribution of contamination in this cross-border region.

The long term monitoring program of surface sediments (up to 0.5 m deep) included inorganic parameters (Ni, Zn, Cd, Cr, Cu, Pb, As and Hg), the USEPA PAHs (PAH₁₆), a large number of pesticides (aldrin, dieldrin, endrin, δ -HCH, heptachlor, heptachlorepoxyde, endosulfan I, DDT and its metabolites), (α -HCH, β -HCH, γ -HCH (lindane) and several polychlorinated biphenyls (PCBs) congeners (28, 52, 101, 118, 138, 153 and 180). The pesticides and PCBs were excluded from further analysis in this work due to their values being below the detection limits. Previous work (Dalmacija et al., 2006; Prica et al., 2008; Krčmar, 2010; Beilicci and Beilicci, 2012) has implied that the pollution in the canal originates from point sources (mainly industrial and urban waste) and diffuse sources along the whole length of the canal (agricultural activity). On a larger regional and European scale, many groups investigating sediment pollution have focused on the parameters investigated (especially the heavy metals and PAHs) (Rippey et al., 2008; Panagos et al., 2013; Gómez-Ramírez et al., 2014; Net et al., 2015; Krčmar et al., 2017).

This paper uses multiple organic and inorganic indicators supported by chemometric analysis in order to determine the degree of geological, anthropogenic and ecological hazards in the examined section of canal, with the view of identifying the further actions required to fully revitalize the canal.

2. Materials and methods

2.1. Sampling sites and sample collection

Begej canal (Romanian name “Bega”) and the river Begej are located in Banat, a region stretching from the eastern part of the Pannonian Plain to the south-western slopes of the Carpathians all the way to the Tisa River, crossing the borders of Serbia, Romania and Hungary (Fig. 1). The combined length of the Begej canal and river is 240 km, 115 km of which is canal. On average, it is about 2.5 m deep, 30 m wide and with a flow of 10–25 m³/s (Dalmacija et al., 2006). The Begej canal represents 2.1 km of the border between Serbia and Romania.

This work examined a 32.3 km stretch of canal from the border between Romania and Serbia to the weir and shipping lock near Klek, focusing primarily on the loess sediment of the canal. In order to identify possible pollution sources and to understand better its severity, sediment was sampled from the canal, analysed in the laboratory, and the results compared with data from the long-term monitoring taken from 2008–2016. The Begej Canal carries considerable amounts of sediment. A large part enters the Canal in Romania through tributaries from the hilly areas located in the east of the river basin. Compared to the tributaries, the canal flow is relatively slow and as a result, slower sections of the canal are characterized by a reduction in water depth and more intense sedimentation. To better understand the degree and severity of the pollution, this study was designed to obtain data from the Canal itself. Based on the above, the research monitoring program was focused on four representative canal sections and included 36 representative sites. The first (I1 – I10) group of sediment profiles encompasses part of the canal downstream from the Serbian-Romanian border, where as a consequence of insufficient maintenance of the vegetation, a decrease in the flow rate occurs, leading to increased sedimentation.

The other (I11 – I20) group includes sites possibility affected by the Itebej lock area (Fig. 2). As a consequence of the political crisis in the region, the locks were closed, leading to a long-term accumulation of contaminated sediment that posed a risk to the environment. At the investigated site, along with shipping lock, a sluice gate was built, which has the role of controlling the overflowing water. Downstream of the sluice gate, the third group (C21 – C30) of samples were taken as possible indicators of the risk on the canal from the water passing through. Sampling sites were divided into



Fig. 1. Map of Northern part of Serbia with location of wider investigated area in Canal Begej (Serbia).

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