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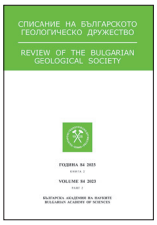

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Application of the DPSIR approach to identify pressures on water resources in the Drina river basin

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Прилагане на подхода DPSIR за определяне на натиска върху водните ресурси в басейна на река Дрина

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Резюме. С нарастването на населението на Земята сме свидетели на бърза урбанизация и развитие на индустрията и селското стопанство. Нови, до голяма степен токсични вещества, се използват в селското стопанство за подобряване на добивите. Всичко това доведе до генерирането на големи количества замърсители, които трябва да бъдат изхвърлени и третирани. Безотговорното поведение и заустванията в природата и речните канали, които не са ясно дефинирани от закона или санкционирани, със сигурност имат въздействие върху околната среда. Басейнът на река Дрина заема части от територите на четири държави. Той е един от най-важните отводнителни артерии на Западните Балкани, за чието поддържане е необходимо международно сътрудничество в много области, като обществено водоснабдяване, напояване, производство на водна енергия и други подобни. Въпреки това, за да се постигне такова сътрудничество, всички страни, които „стопанстват" ресурса, трябва да се ангажират с опазване и защита на качеството на водата. Подходът DPSIR, предложен от Рамковата директива за водите на Европейския съюз, се изпълнява, за да се идентифицират основните видове натиск (източници на замърсяване) в сръбската част на басейна на река Дрина. Напреженията са групирани в няколко категории и описани подробно.

Ключови думи. DPSIR, качество на водата, управление на водните ресурси, Рамкова директива за водите, източници на замърсяване.

Abstract. As the global population grows, we are witnessing rapid urbanization and the development of industry and agriculture. Novel, largely toxic substances are being used in agriculture to improve yields. All of this has led to the generation of large amounts of pollutants that need to be disposed of and treated. Irresponsible behavior and discharges into nature and river channels not clearly defined by law or sanctioned, certainly have an environmental impact. The Drina River Basin occupies parts of the territories of four countries. It is one of the most important drainage areas in the West Balkans. It calls for international cooperation in many areas, such as public water supply, irrigation, hydropower generation, and the like. However, in order to achieve such cooperation, all the countries that "steward" the resource need to commit to water quality conservation and protection. The DPSIR approach proposed by the Water Framework Directive of the European Union is followed to identify major pressures (pollution sources) in the Serbian part of the Drina River Basin. The pressures are grouped into several categories and described in detail.

Keywords: DPSIR, water quality, water resources management, Water Framework Directive, pollution sources.

Introduction

The Drina is a transboundary river that flows along the territories of Serbia, Bosnia & Herzegovina, Montenegro, and in a small part Albania. Given that spacious fertile lowlands in the alluvial plains of large rivers have favored human settlement since time immemorial, this is also the case in the study area. Water is used for multiple purposes, from domestic water supply, irrigation, tourism, sports, recreation (Pecelj et al., 2019) to hydropower generation (Arsić et al., 2009; Pavlović et al., 2021).

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From an energy perspective, the Drina River Basin is among the most prospective in Europe. To date, nine hydroelectric power plants have been built, with a total water storage volume of 2220×10^6 m^3 (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2021).

In view of the above, water management in the Drina River Basin, particularly in terms of resource protection and water quality, certainly represents one of the most important challenges. It requires ongoing monitoring, especially with a view to long-term utilization for a variety of purposes. This topic has been addressed by a large number of West Balkan researchers (Leščešen et al., 2014; Pivić et al., 2014; Gajić et al., 2016; Brankov et al., 2021). Guided by the principles of the Water Framework Directive (WFD) established by the European Union (2000) and relevant Common Implementation Strategy (CIS) guidance documents, the paper describes how the *Driver-Pressure-State-Impact-Response* (DPSIR) framework (2014) can be used to identify existing and potential sources of pollution (pressures), which might or already do affect water quality in the Drina River Basin. The approach has been followed in many studies (Khan, Al-Ghouti, 2021; Parastatidou et al., 2021; Malmir et al., 2022). Pollution sources in Serbia are identified and then grouped into several categories, to make the subject matter easier to follow and understand.

Study area

The Drina River originates at the junction of the Tara and Piva rivers at Šćepan Polje on the border between Montenegro and Bosnia & Herzegovina. It empties into the Sava River in Serbia, at Sremska Rača. The river basin occupies the western part of Serbia, eastern part of Bosnia & Herzegovina, and northern parts of Montenegro and Albania (Fig. 1).

Fig. 1. Drina River Basin (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2021)

The river is 346 km long and the land area of its basin 20 320 km^2. The flow direction is south to north. The average discharge of the Drina just ahead of its mouth is about 400 m^3/s. The paper focuses on the Serbian part of the river basin.

Research methodology

The Water Framework Directive (2000/60/EC) is the most important European document in the field of water policy. It proposes the establishment of a framework for comprehensive protection of all water resources (terrestrial, coastal, underground, and transitional water bodies), considering their natural interaction in both qualitative and quantitative terms, applying the principle of integrated water resources management. The main, primarily environmental objective of the WFD is the implementation of an appropriate Program of Measures to achieve and/or maintain an adequate quantity and quality of surface water and groundwater, as well as to enjoy the benefits of water. The CIS guidance documents were developed to harmonize activities on the implementation of the WFD principles. Based on those principles and CIS Guidance Document 3, the DPSIR approach is followed to analyze pressures and identify pollution sources. This methodology was proposed by the European Environment Agency (EEA, 2014). EEA believes that it is the most adequate framework for identifying early signs of change that might impact the environment, primarily with regard to economic and social activities, but also societal response to such changes. The DPSIR acronym stands for the following: D (driving force) for all human activities that might affect the environment (agriculture, industry, etc.); P (pressures) for direct consequences of human activity grouped by genesis into several categories (illegal waste disposal, wastewater discharges, etc.); S (state) for water body quality as affected by natural and anthropogenic factors; I (impact) for direct ramifications of environmental pressures; and R (response) for environmental response to impacts and changes, which constitute the basis for selecting appropriate activities aimed at planning and implementing adequate measures. Based on this approach and for the purposes of the present study, the main sources of pollution were reviewed and classified as either point sources (population connected to public wastewater management/sanitation systems, industry, landfills) and diffuse sources (population with no access to sanitation and various land uses like farms and forests). In addition, the study area features considerable human hydromorphological pressures, generally associated with hydraulic engineering undertakings that involve rivers. These pressures were taken into consideration because it was believed that they affect both the abiotic characteristics and ecological status of water bodies. Moreover, hydromorphological alterations and their potential impact on the qualitative status of surface water bodies are among the major threats to the achievement of environmental objectives stipulated by the WFD.

Results and discussion

The water quality status in the Drina River Basin in Serbia is affected above all by various point and diffuse sources of pollution and hydromorphological pressures. Symptomatic of point sources (population with access to public sanitation) is the fact that most settlements in the Drina River Basin in Serbia do not have completed wastewater collection, evacuation and treatment systems. Namely, wastewater is usually collected by combined sewage/stormwater systems and discharged untreated into the nearest recipient, usually a watercourse. However, the EU Wastewater Directive (91/271/EEC) requires public sanitation of all agglomerations larger than 2000 population equivalent, wastewater evacuation by public sewer systems, and secondary treatment prior to discharge. Settlements in the Drina River Basin in Serbia, namely the municipalities of Užice, Valjevo, Šabac and Koceljeva, are without full access to urban sanitation. All municipal service locations are downstream from wastewater outlets of the main agglomerations along the Drina and its tributaries. They include the towns of Loznica, Mali Zvornik, Krupanj, Ljubovija, Bajina Bašta, Prijepolje, Sjenica, Priboj, Nova Varoš, and Čajetina (Fig. 2). No municipality or public utility that manages wastewater in the Drina River Basin in Serbia operates a wastewater treatment plant, such that sewage is generally not separated from stormwater. In fact, all wastewater is discharged into rivers. Table 1 below contains a list of public enterprises/utilities in the Drina River Basin in Serbia and shows the amounts of discharged untreated wastewater.

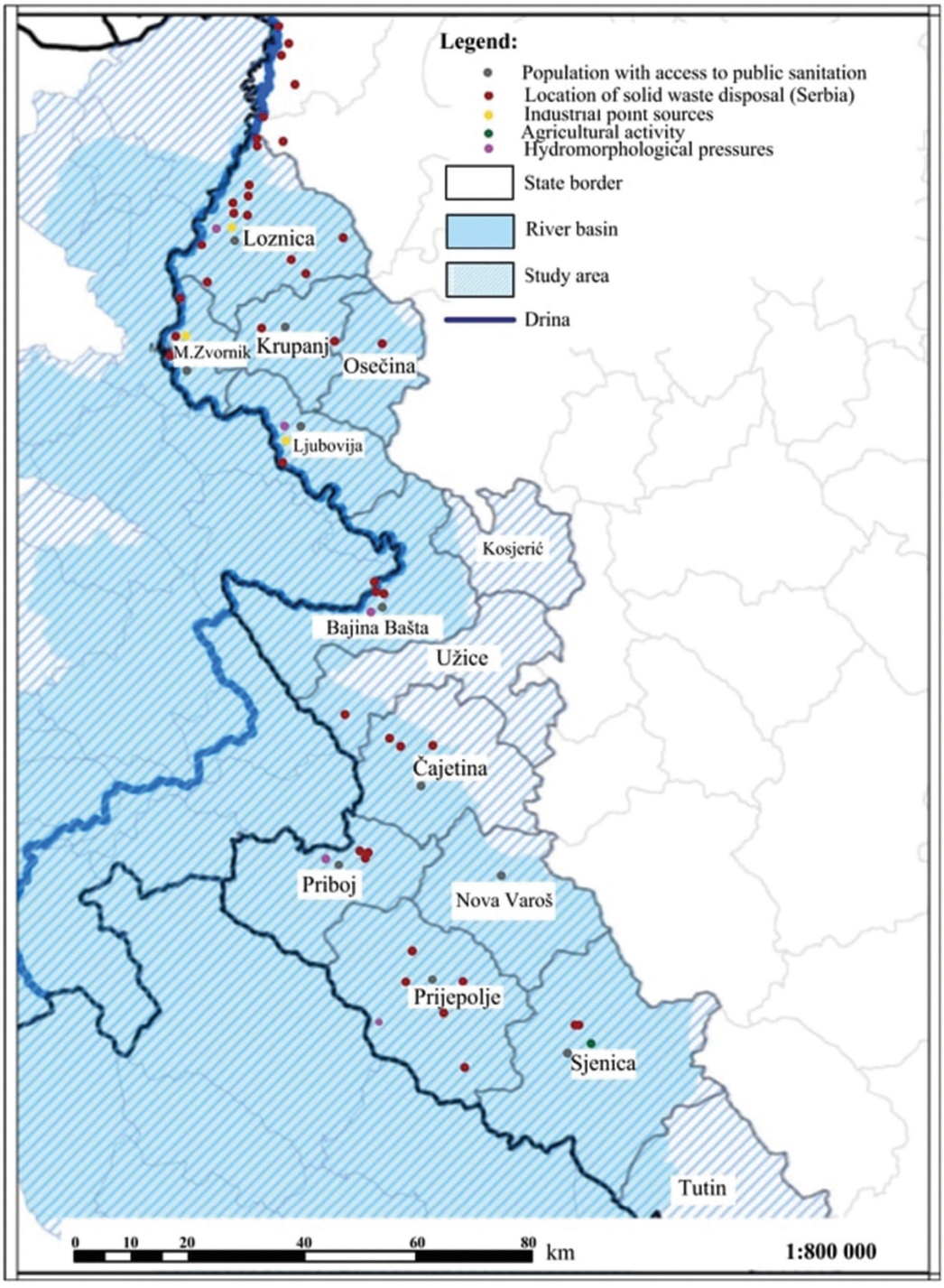

Fig. 2. Location of the main pollutions sources in the Drina River Basin in Serbia (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2021; modified)

It is apparent in Table 1 that most of the wastewater (2 289 528 m^3/yr) is discharged in the catchment of the Uvac River, which is the largest tributary of the Lim River. As such, a certain amount of the wastewater reaches the Drina because the Lim is one of its largest tributaries. Most of the direct discharge into the Drina comes from Bajina Bašta (266 450 m^3/yr). The municipal wastewater load is estimated at 91 000 PE. Industry was the second considered point source of pollution. Seventeen industrial point sources were identified in Serbia, mostly food producers, mines, and quarries. These

Table 1
Public enterprises and utilities in Serbia that discharge untreated wastewater into the Drina River (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2021)

Public enterprise/utility (municipality)	Recipient	River basin/ sub-basin	Treatment prior to discharge	Amount of wastewater (m^3/yr)	EP
PE Water Supply and Sanitation (Loznica)	Stira	Drina	none	148 643.00	34 222
PU Services (Priboj)	Lim	Drina	none	878 707.20	16 000
Lim (Prijepolje)	Lim	Drina	none	649 905.00	10 000
PU 3 September (Nova Varoš)	Bistrica	Uvac	none	540 200.00	9100
PU Vrela (Sjenica)	Grabovica	Uvac	none	2 289 528.00	9000
PU 1 May (Krupanj)	Likodra	Jadar	none	172 280.00	3850
PU Standard (Ljubovija)	Ljubovija	Drina	none	246 007.00	3000
PU 12 September (Bajina Bašta)	Drina	Sava	none	266 450.00	2200
PU Zlatibor (Čajetina)	Obudojevica	Rzav	none	1 728 000.00	2300
PU Drina (Mali Zvornik)	Drina	Sava	None	113 463.00	2300

facilities discharge their wastewater untreated directly into the Drina or its tributaries. They are located in Loznica, Bogatić, Ljubovija, and Mali Zvornik. Solid waste management is a major problem in the Drina River Basin. There are many illegal waste dumps, on riverbanks or even in river channels. In addition, there are no waste incineration or mechanical or biological treatment facilities in the Drina River Basin in Serbia. Consequently, solid waste disposal in regional sanitary or municipal non-sanitary landfills is currently the only option (Fig. 2). There is a regional sanitary landfill (called Duboko) in the Drina River Basin in Serbia, which services the city of Užice, Čačak Municipality, and the towns of Bajina Bašta, Arilje, Požega, Čajetina, Kosjerić, Lučane, and Ivanjica. The municipalities of Nova Varoš, Prijepolje, Priboj and Sjenica are planning to build a regional sanitary landfill (Banjica) in Nova Varoš. In the vicinity of the Drina, non-sanitary landfills that are potential sources of floating waste include Trbušnica in Loznica and Koševine in Krupanj.

The first considered diffuse source of pollution – land use – includes indiscriminate exploitation of forests and related activities (building of forest tracks, use of machinery, setting up of forest construction sites, no soil remediation). These activities enhance erosion and thus the delivery of suspended sediment into rivers. Additionally, washout of fine particles from forest tracks, as a rule with no adequate anti-erosion protection, leads to elevated river water turbidity. At the same time, the rainfall retention time is shortened and runoff accelerated, which has lately been a significant issue because of extreme flood events. It should also be noted that the transportation and storage of fuel and lubricants for machinery and the disposal of used oil are major threats. The second source in this category is the population with no access to public sewers. Given that it was not possible to collect adequate data in this regard for the Drina River Basin, it was assumed that the population uses septic tanks. In Serbia, 63% of the population has no access to sanitation services and this percentage applies to Drina River Basin as well. The main reason is that most municipalities have sewer systems only in urban zones. All municipal service locations are downstream from wastewater outlets of the agglomerations along the Drina and its tributaries, which include Loznica, Mali Zvornik, Krupanj, Ljubovija, Bajina Bašta, Prijepolje, Sjenica, Priboj, Nova Varoš, and Čajetina (Table 2 and Fig. 2). None of the municipalities that manage water resources has a wastewater treatment plant, such that sewage is not separated from stormwater and thus virtually all wastewater is discharged into rivers.

Considering not only the size of the town or municipality, but also household connections to the public water supply and sanitation, Table 2 data show that Loznica has the highest connectivity. Of

Table 2
Household connectivity to public water supply and sanitation (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2021)

Town/municipality	Number of households	Treated wastewater (thou. m^3)	Households connected to public water supply	Households connected to public sanitation	Households with no access to public sanitation
Bajina Bašta	8938	/	4518	4000	4938
Nova Varoš	5903	/	4210	4150	1753
Priboj	9257	/	5240	5142	4115
Prijepolje	11467	/	5447	2910	8557
Sjenica	25798	/	26224	3994	10570
Čajetina	14564	/	26224	3994	10570
Valjevo	85962	4126	31143	20820	65142
Osečina	11113	/	1523	/	11113
Bogatić	8869	/	2366	/	8869
Krupanj	5620	/	2060	1600	4020
Loznica	27127	/	27100	13962	13165
Ljubovija	4852	/	3134	2023	2829
Mali Zvornik	4220	100	3140	1350	2870

a total of 27 127 households, 27 000 have access to the public water supply and 13 962 to sanitation. The connectivity to public sewers is not satisfactory because the numbers of the two types of connections are not aligned. Half of the population (slightly more than 13 000) likely uses private septic tanks, which this study considers a significant diffuse source of pollution. In Osečina Municipality there are 11 113 households, of which only 1523 are connected to the public water supply and based on available data none have access to public sanitation. Apart from that municipality, there is no sewer network in Bogatić and only about one-third of the population is connected to the public water supply. In all other towns/municipalities, except for Nova Varoš, more than half of the population has no access to public sanitation. Wastewaters are discharged directly into the Drina or its tributaries, except in Valjevo, Šabac and Mali Zvornik where they are treated prior to discharge.

Agricultural activity was the last diffuse source of pollution considered in the present research. It is the primary source of pollution of surface water and groundwater in the study area. It originates from indiscriminate use of various types of pesticides and fertilizers, but also the release of other materials such as manure and slurry from farms. In addition to crop farming, livestock raising is a significant economic activity in the Drina River Basin in Serbia, as well as in Bosnia & Herzegovina and Montenegro. Livestock farming is largely practiced by households with a small number of production units. The structure of farms and the output per head of livestock is well below the EU average. Poultry and pig farming are dominant in the Drina River Basin in Serbia. Most of the agricultural activity takes place in the municipalities of Šabac, Valjevo, Bogatić, and Sjenica (Fig. 2).

With regard to hydromorphological pressures, the main drivers are the construction of flood management structures (e.g., regulation constructions/cascades and concrete floodwalls), straightening of river channels, agglomerations with farmland, many settlements adjacent to rivers, proximity of roads and railroads, and small hydroelectric power plants. The flood defenses in the Drina River Basin have been built to protect large settlements, which also host industrial facilities (Bajina Bašta, Loznica and Ljubovija on the Drina, and Priboj, and Priljepolje on the Lim). There are levees only along the most downstream reach of the Drina (Mačva District), in the Jadar River valley and along several tributaries, built to protect farmland (Fig. 2).

Conclusions

The Drina River is an irreplaceable water resource for the population living in the basin. The sources of river pollution in this region are a result of urbaniza-

tion, local communities, industry, agriculture, and shortage of municipal infrastructure, but also lack of ecological awareness and years of inadequate water resources management. Contaminated water in the river basin threatens plants and animals, as well as the human population in general, because it affects agriculture and the food industry by reducing yields and exports due to non-compliance with quality standards. Consequently, a lot of effort and funding are needed to address these issues.

It is especially important to emphasize the importance of pollution of large rivers such as the Drina, which usually are in hydraulic link with groundwater. In Serbia, a large number of groundwater sources for water supply represent alluvial aquifers where there is an intensive hydraulic link between the river and the aquifer. Because of that, any major surface water pollution in such environments will consequently increase the risk or affect groundwater pollution.

The scientific contribution of this paper is raising awareness of the general public about the importance of familiarity with the subject region in general, but also gaining insight into the issues that have prevailed in it for decades. They need to be addressed in a systematic manner, by involving experts in various fields to create an appropriate legal framework that would prohibit waste disposal near watercourses, limit agricultural production on contaminated soil, remediate polluted soil, monitor industrial facilities and municipal services (which need to build wastewater treatment plants in the foreseeable future), build and/or complete sanitation networks in settlements with low connectivity, and the like.

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