

SELF-PURIFICATION CAPACITY AND PHYSICO-CHEMICAL ASSESSMENT ON A RIVER BASIN PRESSURED BY ANTHROPOGENIC INFLUENCES: EXAMPLE OF THE OSAM RIVER, BULGARIA

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ABSTRACT. Various anthropogenic impacts alter the structure and functioning of natural components, and the process of self-recovery in a damaged environment is more relevant than ever. Water quality worsens due to pollution with organic and inorganic chemical substances, and understanding the ability of aquatic streams to self-purify is a key challenge facing the scientific community. This article, dedicated to the Osam River (Bulgaria), provides knowledge on how eight physico-chemical elements change their concentrations from upper to lower reaches and to what extent the river manages to self-purify of pollutants. The paper is based on information concerning the values of DO₂, N-NH₄, N-NO₃, N-NO₂, N-tot, P-PO₄, P-tot, and BOD₅, recorded at four sampling sites from 2015 until 2021. Water quality is classified into one of three classes of physico-chemical status (excellent, good, or moderate) following the guidelines in Regulation H-4/14.09.2012 for surface water characterization. The self-purification coefficient of Tumas (α) is computed to determine the extent to which the river is able to rid itself of pollutants. The results indicate that water quality changes from upstream to downstream due to the inflow of untreated wastewater discharged from various sources and the ongoing self-purification processes. In the upper section, the river fails to get rid of phosphate pollution caused by households and industry, while in the lower sector, nitrate loading from agriculture is most disturbing. The current research focuses on the ability of rivers to restore their natural conditions under various anthropogenic impacts and points to the need for more effective control of unregulated discharges.

KEYWORDS: self-purification ability, physico-chemical status, anthropogenic impact

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INTRODUCTION

Water is one of the components of the environment that is most strongly and complexly subjected to a multivariate anthropogenic impact. The disruption of the normal aquatic ecosystem functioning is a consequence of water pollution, primarily resulting from anthropogenic pressures (Hishe et al. 2020; Sakke et al. 2023). The prolonged and continuous discharge of polluting substances is associated with a decrease in the water's self-purification ability, causing a hydro-ecological imbalance (Midyurova et al. 2021). The main sources of water loading with substances of various origins and compositions include agriculture, industry, the communal-household sector, transport, tourism, the character of land use, etc. (Zhang M et al. 2022), and rarely, some natural processes, such as erosion (Chalov et al. 2024).

According to the ecosystem approach, applied in the hydro-ecological practice, watercourses under certain conditions are able to restore their initial quality based on the ongoing biological, physical, chemical, and hydrodynamic processes. There are different definitions regarding the river water's self-purification. For example, it can be expressed as a partial or a complete restoration of the original state of water masses through natural processes (Benoit 1971). Another definition of self-purification states that it involves reduction in the content of pollutants entering in the water after a certain period or distance from the point of entry (Ignatova 1992) or that the aquatic environment responds to the entry of pollutants through a number of mechanisms aimed at restoring its original state (Vismara 1992). The process of self-purification consists of various complex phenomena,

involving numerous physical, chemical, and biological factors, acting and interacting more or less effectively. The scientific expression of the ability of river streams to self-purify (Bukaveckas 2007; Alexander et al. 2009), as well as the quantification of the water's self-purification capacity today is a relevant and complex research issue (Zhang X et al. 2022).

The review of the scientific publications addressing the problem of the rivers' self-restoration indicates the application of various methods, approaches, and techniques in determining their self-purification capacity. Vagnetti et al. (2003) found a significant reduction in the content of pollutants in water samples taken at the beginning and end of the Sile River in the Veneto Region, Italy, through statistical processing of existing data. The researchers draw conclusions about which elements show a significant reduction in values and formulate possible interpretations. Fisenko (2006) presents a model of a process for self-purifying river streams along the Mimico Creek in the Ontario Province, Canada, through a natural foam formation. To determine the self-purification capacity of river flows, Mala and Maly (2009) focus on assessing the toxic effect of heavy metals on biochemical oxygen demand (BOD_5) in surface waters of the Svratka River in the Brno District, Czech Republic. Self-purification of rivers occurs at a certain distance from the point where polluting substances enter and involves several processes (dilution, sedimentation, reaeration, adsorption, absorption, and both chemical and biological reactions). This complex mechanism of cleaning polluted water can be evaluated through various mathematical models. Menezes et al. (2015) and Salih et al. (2021), dealing with river basins at different spatial scales in Brazil and Iraq, use models that focus on the content of dissolved oxygen (DO_2), which is one of the crucial indicators for aquatic ecosystems and the water's self-purification processes. Hishe et al. (2020), applying the Streeter-Phelps model, assess the impact of point source pollutants from industry on the water's self-purification ability along the Abay River, Ethiopia. Zhang X et al. (2022), using the SWAT model, estimate the effect of non-point source pollutants on water's self-purification of the Yiluo River, China. Medupe and Letshwenyo (2025) leverage advanced predictive models and algorithms to offer real-time insights and future projections regarding self-purification for a tributary of the Limpopo River, Botswana. Gurjar and Tare (2019) and Xu et al. (2019), working with Bayesian Networks, evaluate the influence of land use and sewage outfalls on water's self-purification capabilities for tributaries of the Ganges River (India) and the Yangtze River (China), respectively. The surface water's self-purification by determining the distribution of nitrate (NO_3) and phosphate (PO_4) concentrations for natural and regulated stretches along the Nemunas River, Lithuania has been studied by Šaulys et al. (2020). The method proposed by the authors for comparing the amount of pollutants entering and leaving a certain section is, in practice, the most objective way to assess the self-purification capacity along the course of a given river.

Like a number of river systems in the Republic of Bulgaria, the catchment area of the Osam River is characterized by diverse natural conditions and the development of different socio-economic activities (agricultural, industrial, communal-household, etc.) (Gartsyanova et al. 2023). The past studies (Gartsyanova 2015; Gartsyanova and Varbanov 2015) on the water quality of this river reported continuous pollution with chemical substances of various origins and compositions whose concentrations are changing from upstream to downstream (Seymenov 2022). This, in turn,

implies variable self-purification ability along the river's course.

The present article builds on previous studies dealing with the water quality of the Osam River and is the first to focus on its capacity to dilute the entering pollutants. This paper aims to evaluate the Osam River's water self-purification ability by analyzing selected physico-chemical elements in three sections along its course for the period 2015–2021.

MATERIALS AND METHODS

Study area

The Osam River is the second longest tributary of the Danube River in the Republic of Bulgaria, with a total length of 314 km and a catchment area of 2824 km² (Hristova 2012) (see Fig. 1).

The main river is formed from the tributaries Beli Osam River (a left branch) and Cherni Osam River (a right branch), merging at the northern outskirts of the town of Troyan. The longer of them, the Cherni Osam River, has a total length of 36 km and takes its source on the western foothills of the Levski Peak (2166 m a.s.l.), Central Balkan Mountains (Hristova 2012). In this part, the river runs north in a deep, narrow valley. Later, the river enters the Central Fore-Balkans, where between the towns of Lovech and Levski flows northeastern in a canyon-like valley through a karst terrain. Downstream after the town of Levski, the river crosses the Central Danube Plain in a northwesterly direction and forms an asymmetrical valley with flat left and steeper right slopes. The riverbed widens and, due to the low gradient, meanders in all directions. The Osam River empties into the Danube River not far from the village of Cherkovitsa at 22 m a.s.l. (Hristova 2012). The Osam River receives mostly short left- and right-bank tributaries, forming a narrow-shaped drainage basin with an expanded middle part (see Fig. 1).

The region is characterized by temperate-continental climatic conditions with a transition to mountainous with increasing altitude. The mean annual air temperature ranges from 9.0°C to 11.5°C. Winter temperatures are around -2.5°C, but decrease to -5.0°C toward the river's source, while summer temperatures reach 23°C. The annual sum of precipitation varies from 550–600 mm to 1000–1200 mm. The rainiest month is May or June, while the driest is February (Velev 2010). The Osam River has a mixed-type feed of snow, rain, and karst water (Hristova 2012). Snow and rain feed is prevalent in the Balkan Mountains, rain in the Danube Plain, and karst water in the Fore-Balkans. The average annual streamflow is increasing in a flowing direction, varying from 3.42 m³/s (the Beli Osam River at Troyan) up to 14.10 m³/s (the Osam River at Sanadinovo). The runoff regime is marked by a high water level in spring (April and May) and a low flow phase in late summer and autumn (September and October) (Hristova 2012). The water resources of the Osam River are utilized for irrigation, household, and industrial needs. There are also several small hydropower plants and balneological complexes. In the Balkan Mountains, the drainage basin is covered by deciduous forests, transitioning to low-stemmed woods and bushes in the Fore-Balkans and arable lands in the Danube Plain. The catchment area occupies parts of Lovech and Pleven Districts and concentrates a total of 88 settlements.

The combination of steep slopes, persistent snow cover, hydrothermal springs, and forest vegetation in the mountainous section, on the one hand, and flat relief with fertile soils in the plain sector, on the other hand,

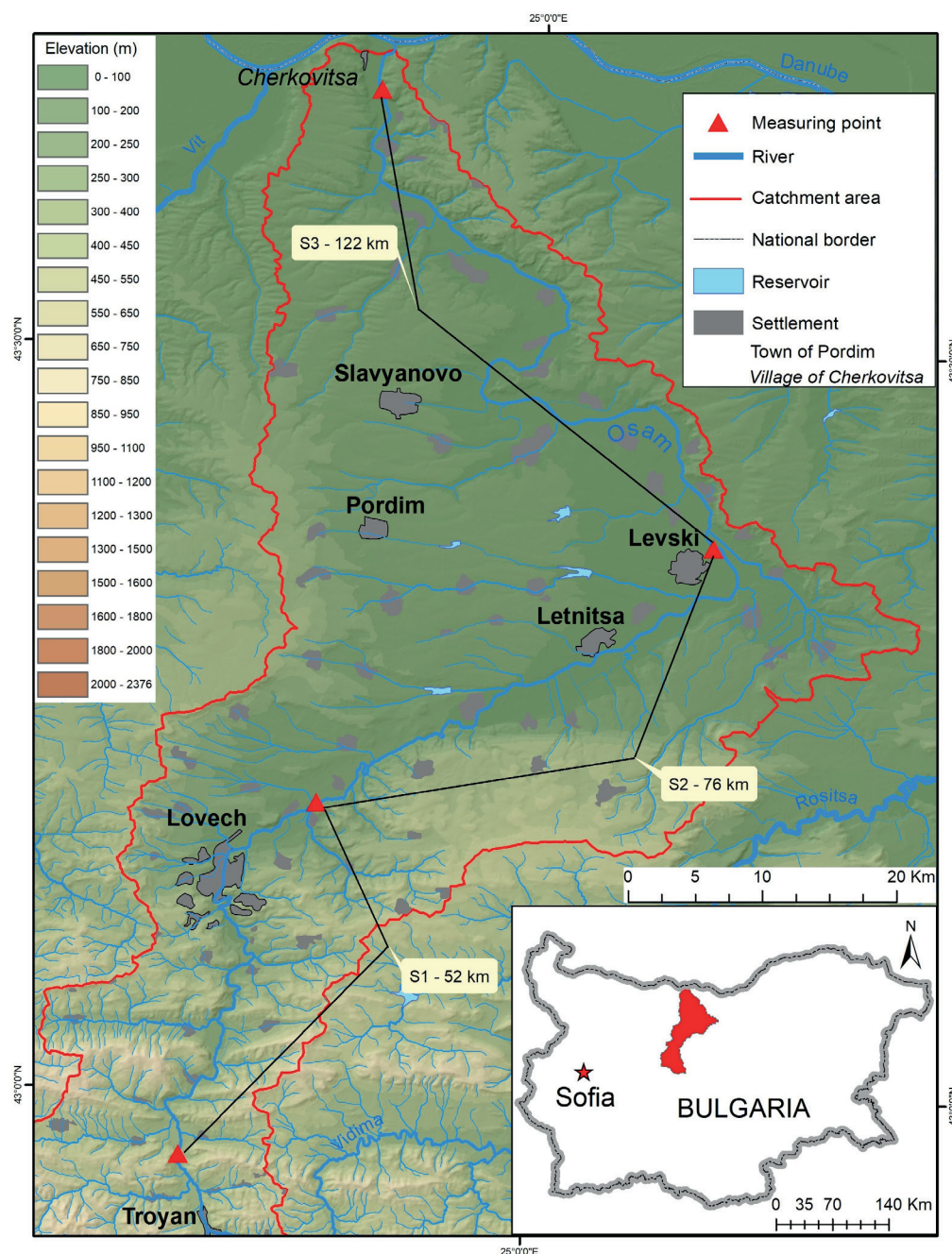


Fig. 1. Map of the Osam River Basin showing the location of settlements, water measuring points, and river stretches

is a prerequisite for the development of various socio-economic activities that are potential sources of surface water pollution (Gartsyanova et al. 2023). The different natural conditions and anthropogenic practices in the upper and lower sections of the catchment area imply variable self-purification capacity for the river.

Data and Methodology

Water samples were collected according to the requirements of the Water Framework Directive 2000/60/EC and their equivalent criteria, transposed into Regulation H-4/14.09.2012 for surface water characterization. The concentrations of eight physico-chemical elements: dissolved oxygen (DO_2), ammonium nitrogen (N-NH_4), nitrate nitrogen (N-NO_3), nitrite nitrogen (N-NO_2), total nitrogen (N-tot), orthophosphates (P-PO_4), total phosphorus (P-tot), and biochemical oxygen demand (BOD_5) were used. The time-series data consists of 28 measurements taken from 2015 until 2021, with sampling four times per year or at least once per season. The output information was collected and published by the Executive

Environment Agency (EEA) and processed using standard statistical procedures by the authors.

According to the mean annual values of each variable, water quality is assigned to one of the three classes of physico-chemical status following Regulation H-4/14.09.2012 for surface water characterization (see Table 1).

The observations were conducted at four water sampling sites (see Table 2). The measuring points, falling within surface water bodies of types R4 (Semi-mountainous streams in a Pontic province) and R7 (Large tributaries of the Danube River), were selected so that they cover parts of the upstream, midstream, and downstream of the examined river (see Fig. 1).

For an assessment of the self-purification ability, three stretches along the investigated river were distinguished (see Fig. 1, Table 3).

The water's self-purification coefficient of Tumas (2003), comparing the amount of pollutant entering and leaving a certain river section, and being in practice the most objective way to assess the self-restoration capacity along the course of a river, was applied in this study. The

Table 1. Status classification according to the physico-chemical elements as stated in Regulation H-4/14.09.2012 for surface water characterization

Water body types	Status	Physico-chemical elements							
		DO _{2'} mg/L ⁻¹	N-NH _{4'} mg/L ⁻¹	N-NO _{3'} mg/L ⁻¹	N-NO _{2'} mg/L ⁻¹	N-tot, mg/L ⁻¹	P-PO _{4'} mg/L ⁻¹	P-tot, mg/L ⁻¹	BOD _{5'} mg/L ⁻¹
R4	Excellent	>8.0	<0.04	<0.5	<0.01	<0.5	<0.02	<0.025	<1.2
	Good	8.0–6.0	0.04–0.4	0.5–1.5	0.01–0.03	0.5–1.5	0.02–0.04	0.025–0.075	1.2–3.0
	Moderate	<6.0	>0.4	>1.5	>0.03	>1.5	>0.04	>0.075	>3.0
R7	Excellent	>7.0	<0.1	<0.7	<0.03	<0.7	<0.07	<0.15	<2.0
	Good	7.0–6.0	0.1–0.3	0.7–2.0	0.03–0.06	0.7–2.5	0.07–0.15	0.15–0.3	2.0–4.0
	Moderate	<6.0	>0.3	>2.0	>0.06	>2.5	>0.15	>0.3	>4.0

Table 2. Information about water measuring points

Type of the water body	Number of the water body	Location of the measuring point		
		Description	Geographic coordinates	
			X (°E)	Y (°N)
R4	BG1OS700R1001	The Osam River after the town of Troyan	24.686	42.957
R4	BG1OS700R1001	The Osam River after the town of Lovech	24.804	43.195
R7	BG1OS700R1011	The Osam River after the town of Levski	25.163	43.371
R7	BG1OS130R1015	The Osam River at the village of Cherkovitsa	24.848	43.674

Table 3. Information about river stretches

River stretches	Altitude (m) of the river stretch		Slope (%) of the river stretch	Length (km) of the river stretch
	At the beginning	At the end		
The Osam River after Troyan – the Osam River after Lovech	380	200	3.50	52
The Osam River after Lovech – the Osam River after Levski	200	50	2.00	76
The Osam River after Levski – the Osam River at Cherkovitsa	50	30	0.16	122

coefficient was calculated for each of the eight physico-chemical variables, using the Eq. 1:

$$\alpha = \ln(C_o C_L^{-1}) L^{-1} \quad (1)$$

where: C_o – a concentration (mg/L⁻¹) of a physico-chemical element at the beginning of the river stretch; C_L – a concentration (mg/L⁻¹) of a physico-chemical element at the end of the relevant stretch; L – length of the river stretch (km); $\ln$ – natural logarithm, and α – a self-purification coefficient.

This coefficient is preferred due to its simplicity of operation, sensitivity of parameters, and informative results. So far, it has been applied by Šaulys et al. (2020) to compare the water's self-purification capacity in terms of NO₃ and PO₄ for natural and regulated river stretches along the Nemunas River (Baltic Sea Basin, Lithuania). Montreuil et al. (2010) used a modified version of this coefficient to evaluate the impact of riparian wetlands on the values of NO₃ along the course of the Scorff River (Atlantic Ocean Basin, France). The authors concluded for which stretches the reduction in the monitored concentrations was significant and formulated possible interpretations. The coefficient has not been used in the Republic of Bulgaria until now.

A key point using this coefficient is the selection of river stretches, their beginning, end, and length. It is

assumed that the length of the river stretch has a direct impact on the results obtained. In general, rivers need a certain distance to dilute pollutants, and selecting too short segments can lead to worse results (Tumas 2003). If conditions allow, the stretches should have approximately equal length. The slope gradients, soil types, topography, vegetation species and distribution, and anthropogenic practices could also influence the value of the self-purification coefficient (Tumas 2003). A higher value, for example, could be impacted by the adjacent permanent grasslands and forests. The dilution of polluted water with surface flow and groundwater can also affect it (Šaulys et al. 2020). On the other hand, a lower value typically indicates an uncontrolled discharge of untreated wastewater from industrial activities, which has a direct, often deleterious effect on water quality (Šaulys et al. 2020). If obtained ratings are less than zero, the stream fails to dilute the entering pollutants. Negative scores indicate that excessive amounts of chemical contaminants are disposed of in the river, so it is incapable of treating itself (Montreuil et al. 2010).

RESULTS and DISCUSSION

Statistical processing of monitoring data demonstrates spatial and temporal variations in the values of the physico-chemical elements along the Osam River (see Tables 4–5).

Table 4. Average multi-annual values of physico-chemical elements for 2015–2021 and status assessment according to Regulation H-4/14.09.2012 for surface water characterization

Measuring points	Physico-chemical elements							
	DO _{2'} mg/L ⁻¹	N-NH _{4'} mg/L ⁻¹	N-NO _{3'} mg/L ⁻¹	N-NO _{2'} mg/L ⁻¹	N-tot, mg/L ⁻¹	P-PO _{4'} mg/L ⁻¹	P-tot, mg/L ⁻¹	BOD _{5'} mg/L ⁻¹
The Osam River after Troyan	8.037	0.152	0.648	0.017	1.138	0.027	0.038	3.079
The Osam River after Lovech	8.150	0.146	0.970	0.015	1.524	0.088	0.105	3.463
The Osam River after Levski	8.512	0.223	2.258	0.042	3.110	0.054	0.069	4.102
The Osam River at Cherkovitsa	7.435	0.187	2.355	0.020	3.048	0.057	0.078	3.758

Note: Status of water: excellent (blue), good (green), and moderate (yellow)

The physico-chemical variables most often failing to meet the requirement of Regulation H-4/14.09.2012 for surface water bodies of type R4 are N-tot, P-PO_{4'}, P-tot, and BOD_{5'} with average values falling within the numerical ranges for “moderate” status. Due to the increase/decrease in pollutant concentrations, as well as the more liberal reference standards, the failed variables for surface water bodies of type R7 include mostly N-NO_{3'} and N-tot (see Tables 4–5)¹.

The analysis of the temporal variability of the physico-chemical elements, as well as the review of past studies, shows that the Osam River's water fails to achieve “good” status for the last three decades. Gartsyanova (2015) and Gartsyanova and Varbanov (2015), exploring the water quality status at the measuring point after Lovech during the period 1990–2014, reported an elevated content of N-NH_{4'} and N-NO_{3'} from 1990 to 1993, N-NO_{2'} between 1994 and 2007, and P-PO_{4'} from 1998 to 2009. The cited authors found continuous pollution with N-NH_{4'} and P-PO_{4'} between 1996 and 2005 at the measuring sites after Levski and near Cherkovitsa, and stated that the highest observed concentrations of these elements exceeded from 10 to 25 times the reference norms for “good” status pointed in Regulation H-4/14.09.2012 for surface water characterization. The deteriorated water quality for the reported periods was mainly influenced by the unregulated discharge of untreated wastewater from households, industrial enterprises, and agricultural lands. The current results show another situation – the mean annual values of the failed variables for 2015–2021 exceed no more than three times the reference standards. This contradiction confirms the positive tendency in the water quality status, already established by Gartsyanova (2015) and Seymenov (2022), and suggests that the Osam River's water continues to improve its physico-chemical conditions between 2015 and 2021. Recently, the study area has been strongly affected by the negative natural population growth, depopulation and emigration, the closure of industrial factories, and the crisis in agriculture. All of these adverse socio-economic processes contributed to reducing of the anthropogenic impact on water quality.

The analysis of spatial variations of the physico-chemical elements finds that the content of N-NO_{3'} and N-tot is increasing in a flowing direction, while the concentrations of the rest of the variables are increasing/decreasing from one measuring point to another (see Tables 4–5). This result partially confirms the study of Seymenov (2022), dealing with the spatial distribution of biogenic substances along the river.

As per the location of water measuring points, the river's course could be divided into three stretches (see Fig.

1, Table 3). The first sector is marked by increasing content of DO_{2'}, N-NO_{3'}, N-tot, P-tot, P-PO_{4'}, and BOD_{5'} and declining values of N-NH_{4'} and N-NO_{2'}. The second stretch has rising concentrations of all elements, excluding P-PO_{4'} and P-tot. The third sector is characterized by growing content of N-NO_{3'}, P-PO_{4'}, and P-tot and falling values of the rest of the variables (see Table 4).

The changes in the average concentrations, determined at the beginning and the end of the river stretches, as well as the computed self-purification coefficient values, show that the Osam River's water self-purifies better in the downstream section (see Fig. 2, Table 6).

In the upper part between Troyan and Lovech, almost all the time the river fails to dilute N-NO_{3'}, N-tot, P-PO_{4'}, and P-tot (see Fig. 2, Table 6). Although the entire river stretch is surrounded by permanent forests and natural grasslands covering steep mountainous terrain, i.e., the bank erosion is prevented, the flow rate is higher, and the detention of pollutants is lower, concentrations of polluting substances are gradually increasing. The untreated or partly treated domestic and industrial effluents released from settlements with incompletely developed sewage systems are the main factors deteriorating upstream water quality. In the mid-stretch between Lovech and Levski, the river manages to self-purify regarding P-PO_{4'} and P-tot but worsens its status as per N-NH_{4'}, N-NO_{3'}, N-NO_{2'}, and N-tot (see Fig. 2, Table 6). In this part, the river enters flat terrain with arable lands, whereat it slows down its flow, which to some extent explains the growing values of nitrogenous compounds. In the lower unit between Levski and Cherkovitsa, the river self-purifies in terms of almost all elements, especially N-NH_{4'}, N-NO_{2'}, and BOD_{5'} (see Fig. 2, Table 6). Although the entire river stretch is abundant in meanders, i.e., the flow rate is lower and the detention of pollutants is higher, the river restores its water quality. Moreover, the surrounding farmlands release waste masses containing fertilizers and pesticides, but despite this, pollutant concentrations are decreasing. The higher rates of the self-purification coefficient can be explained by the dilution of wastewater with the surface flow and their connection with groundwater. It should be mentioned the relatively greater length of this stretch compared to the remaining two, but nevertheless, the river water's diluting ability is obvious.

The temporal analysis does not find a trend toward a decrease or increase in the water's self-purification capacity throughout the period. The upstream stretch is characterized by a worse ability to restore its condition in 2021, with the lowest coefficient ratings for three of the eight elements, and a better capacity to self-purify in 2016 and 2020, with positive scores for half of the indicators. Conversely, the mid-stretch achieved more negative results

¹Such assessments were also reported in the second edition of the River Basin Management Plan (2016–2021), published by the Danube River Basin Directorate. Available from: www.bd-dunav.org/ (last accessed: 16.08.2025).

Table 5. Average annual values of physico-chemical elements and status assessment according to Regulation H-4/14.09.2012 for surface water characterization

Measuring points	Years	Physico-chemical elements							
		DO _{2'} mg/L ⁻¹	N-NH _{4'} mg/L ⁻¹	N-NO _{3'} mg/L ⁻¹	N-NO _{2'} mg/L ⁻¹	N-tot, mg/L ⁻¹	P-PO _{4'} mg/L ⁻¹	P-tot, mg/L ⁻¹	BOD _{5'} mg/L ⁻¹
The Osam River after Troyan	2015	9.800	0.088	0.675	0.012	1.115	0.044	0.051	3.475
	2016	10.100	0.090	0.570	0.006	0.680	0.037	0.044	2.100
	2017	7.066	0.086	0.381	0.022	0.669	0.016	0.028	3.600
	2018	7.338	0.120	0.906	0.012	1.219	0.022	0.030	2.650
	2019	6.500	0.226	0.546	0.025	1.607	0.032	0.041	2.766
	2020	6.630	0.247	0.790	0.020	1.308	0.021	0.046	4.500
	2021	10.750	0.227	0.465	0.015	1.000	0.015	0.021	1.185
The Osam River after Lovech	2015	10.675	0.070	0.907	0.014	1.965	0.082	0.090	5.900
	2016	7.200	0.060	0.670	0.012	0.750	0.031	0.040	3.200
	2017	7.433	0.087	0.693	0.008	0.937	0.095	0.108	2.160
	2018	7.527	0.097	1.587	0.010	1.985	0.073	0.092	2.025
	2019	6.333	0.246	0.733	0.012	1.830	0.092	0.105	3.100
	2020	6.966	0.289	1.206	0.013	1.790	0.012	0.016	5.430
	2021	9.275	0.147	0.698	0.034	1.215	0.095	0.106	1.916
The Osam River after Levski	2015	10.800	0.195	2.300	0.051	3.970	0.049	0.061	4.525
	2016	11.500	0.070	1.800	0.018	1.900	0.045	0.052	2.800
	2017	6.300	0.220	2.113	0.045	2.443	0.074	0.085	3.283
	2018	7.425	0.136	2.657	0.030	3.385	0.054	0.056	4.510
	2019	6.067	0.402	1.953	0.051	2.696	0.057	0.088	3.453
	2020	7.433	0.253	2.270	0.047	3.073	0.044	0.069	4.900
	2021	7.900	0.120	1.872	0.036	2.430	0.058	0.077	2.320
The Osam River at Cherkovitsa	2015	10.400	0.075	2.600	0.022	4.150	0.050	0.066	3.530
	2016	8.500	0.067	2.100	0.015	2.310	0.057	0.058	6.300
	2017	5.525	0.159	2.863	0.016	2.900	0.058	0.070	3.600
	2018	5.550	0.178	2.443	0.019	3.292	0.069	0.100	2.175
	2019	6.530	0.276	1.906	0.018	2.436	0.054	0.065	6.266
	2020	7.700	0.428	2.460	0.024	3.130	0.084	0.104	5.020
	2021	8.475	0.113	1.963	0.023	2.525	0.046	0.073	2.225

Note: Status of water: excellent (blue), good (green), and moderate (yellow)

in 2016 and positive ones in 2021. The downstream section generally demonstrates a higher ability to self-purify over the years (see Table 6). This variability confirms that river water's self-purification is a complex process involving multiple factors acting simultaneously and interacting more or less effectively.

CONCLUSIONS

The conducted research focused attention on a relatively poorly studied issue related to the capacity of

ivers to restore their natural conditions under various anthropogenic pressures. The obtained results showed continuous pollution along the selected river, but with a general trend toward improvement in water quality. The applied self-purification coefficient was an informative and easy-to-use approach for assessing the ability of the watercourse to get rid of contaminants. The calculated ratings revealed that in the upper stretch the river is unable to self-purify, while in the lower section the streamflow and inflowing groundwater dilute the entering pollutants and thus contribute to the decrease in their concentrations.

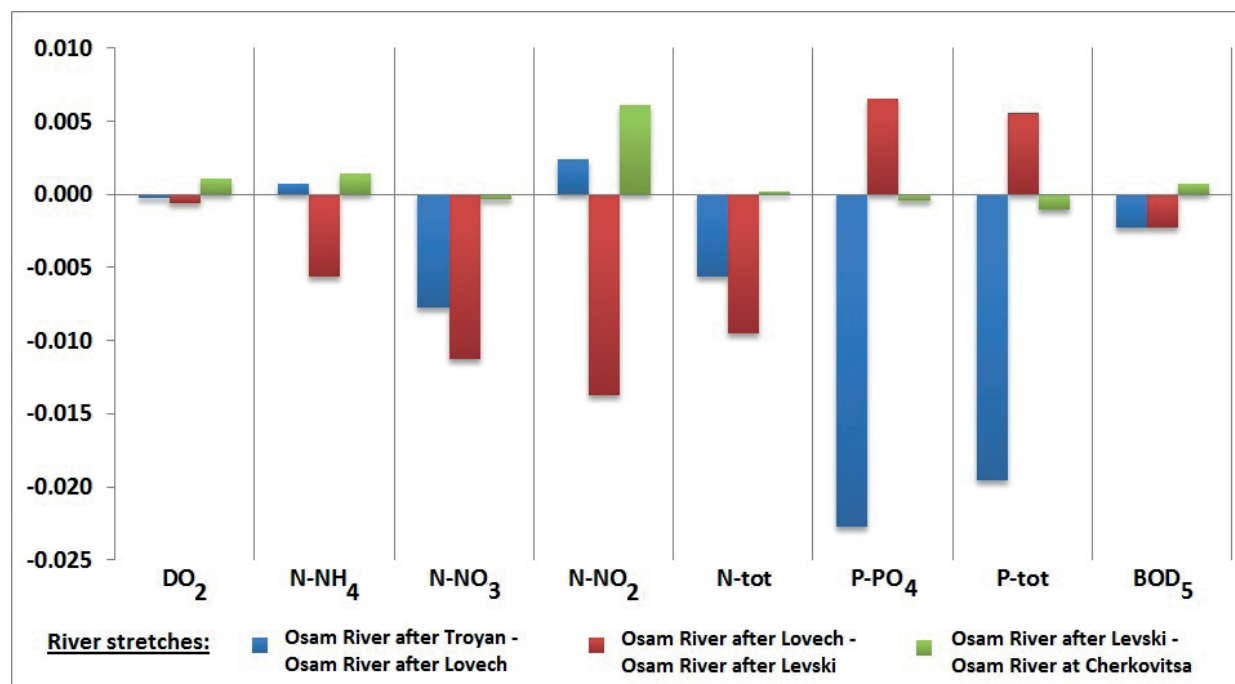


Fig. 2. Self-purification coefficient ratings based on the average multi-annual values of physico-chemical elements for 2015–2021

Table 6. Self-purification coefficient ratings based on the annual values of physico-chemical elements

River stretches	Years	Physico-chemical elements							
		DO ₂	N-NH ₄	N-NO ₃	N-NO ₂	N-tot	P-PO ₄	P-tot	BOD ₅
The Osam River after Troyan – the Osam River after Lovech	2015	-0.002	0.003	-0.006	-0.003	-0.011	-0.012	-0.011	-0.010
	2016	0.007	0.008	-0.003	-0.013	-0.002	0.003	0.002	-0.008
	2017	-0.001	0.000	-0.012	0.019	-0.006	-0.034	-0.026	0.010
	2018	0.000	0.004	-0.011	0.004	-0.009	-0.023	-0.022	0.005
	2019	0.001	-0.002	-0.006	0.014	-0.002	-0.020	-0.018	-0.002
	2020	-0.001	-0.003	-0.008	0.008	-0.006	0.011	0.020	-0.004
	2021	0.003	0.008	-0.008	-0.016	-0.004	-0.035	-0.031	-0.009
The Osam River after Lovech – the Osam River after Levski	2015	0.000	-0.013	-0.012	-0.017	-0.009	0.007	0.005	0.004
	2016	-0.006	-0.002	-0.013	-0.005	-0.012	-0.005	-0.003	0.002
	2017	0.002	-0.012	-0.015	-0.023	-0.013	0.003	0.003	-0.006
	2018	0.000	-0.005	-0.007	-0.015	-0.007	0.004	0.007	-0.011
	2019	0.001	-0.007	-0.013	-0.019	-0.005	0.006	0.002	-0.001
	2020	-0.005	0.002	-0.008	-0.017	-0.007	-0.018	-0.019	0.001
	2021	0.002	0.003	-0.013	-0.001	-0.009	0.007	0.004	-0.003
The Osam River after Levski – the Osam River at Cherkovitsa	2015	0.000	0.008	-0.001	0.007	0.000	0.000	-0.001	0.002
	2016	0.002	0.000	-0.001	0.001	-0.001	-0.002	-0.001	-0.007
	2017	0.001	0.003	-0.002	0.009	-0.001	0.002	0.002	-0.001
	2018	0.002	-0.002	0.001	0.004	0.000	-0.001	-0.005	0.006
	2019	-0.001	0.003	0.000	0.009	0.001	0.000	0.002	-0.005
	2020	0.002	-0.004	-0.001	0.006	0.000	-0.005	-0.003	0.000
	2021	-0.001	0.000	0.000	0.004	0.000	0.002	0.000	0.000

The study concludes that active actions are needed to prevent pollutants from entering the riverbed and to improve the self-purification capacity of surface water. The so-called soft naturalization measures are proposed. These include planting riparian protection zones along the riverbanks with connection to the surrounding wetlands in floodplains, maintaining well-aerated water by allowing woody vegetation to grow on river slopes, forming natural barriers and obstacles to water flow, etc. Stricter measures should be considered to limit the inflow of untreated wastewater into the river from agricultural, industrial, and residential sources.

This article evaluates the water quality status only in terms of averaged annual and multi-annual concentrations, but monthly and seasonal variations of physico-chemical elements are also significant factors that should be taken into account to fully assess the self-purification ability. This fact necessitates more frequent and regular monitoring of water quality elements. In the future, this work could be extended with additional indicators, such as river runoff, water temperature, etc., to obtain a comprehensive understanding of the self-purification mechanism. ■

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