THE IMPACT OF HYDRO-TECHNICAL WORKS ON AQUATIC ECOSYSTEMS. STUDY CASE: THE JIU RIVER FROM THE SPRINGS TO THE DANUBE CONFLUENCE

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Abstract. The paper discusses the results obtained by the team of specialists regarding the impact of the most important hydrotechnical works on the Jiu River, i.e. damming, regularization and transverse barrage works, focusing on the Livezeni, Vădeni, Târgu-Jiu, Turceni and Işalniţa permanent accumulation dams, and presenting their effects on the composition of aquatic biocenoses, respectively on the state or ecological potential of the water bodies designated on the Jiu River. The study covers the course of the river from the springs up to the confluence with the Danube River. In order to evaluate the anthropogenic impact of hydro-technical works, physical, chemical and biological indicators were used according to DCA 60/2000/CE and different methods were applied: the water quality index method (ICA), the global pollution index method (GI) and the matrix method according to the relevant literature. For the water quality index (ICA), data related to the bacteriological load of the investigated water body were additionally used. All methods were harmonized with the interpretations proposed by DCA 60/2000/CE in order to have a unitary assessment of the anthropogenic impact on water bodies and to synchronize the obtained results with the new method proposed by this project (Taxonomic Correspondence Index-ICT). The materials used in this research are samples collected for physical-chemical, biological and bacteriological determinations, respecting the sampling and analysis technique in accordance with the regulations in force. The methods for evaluating the anthropogenic impact using biological parameters were represented by relative cleanliness (C%), relative impurity (I%), the Saprobic index method (S), the species scarcity method and the EPTT index method (*Ephemeroptera, Plechoptera, Trichoptera*, groups with species sensitive to anthropogenic impact).

Keywords: water body, anthropic impact, aquatic biocenoses, hydrotechnical works.

Rezumat. Impactul lucrărilor hidrotehnice asupra ecosistemelor acvatice. Studiu de caz: râul Jiu izvor-confluență Dunăre. Lucrarea aduce în discuție rezultatele obținute de echipa de specialiști referitoare la impactul celor mai importante lucrări hidrotehnice de pe râul Jiu, lucrări de îndiguire, de regularizare și de barare transversală, studiul fiind concentrat pe barajele acumulărilor permanente Livezeni, Vădeni, Târgu-Jiu, Turceni şi Işalniţa, prezentându-se efectele acestora asupra compoziţiei biocenozelor acvatice, respectiv asupra stării ori potenţialului ecologic al corpurilor de apă desemnate pe râul Jiu, studiul pornind de la izvoare și pâna la confluență cu Fluviul Dunărea. Pentru a evalua impactul antropic al lucrărilor hidrotehnice s-au folosit indicatori fizico-chimici și biologici conform DCA 60/2000/CE și s-au aplicat diferite metode: metoda indicelui de calitate a apei (ICA), metoda indicelui global de poluare (IG) şi metoda matriceală conform literaturii de specialitate. Pentru indicele de calitate a apei (ICA) s-au folosit în plus și date referitoare la încărcarea bacteriologică a corpului de apă cercetat. Toate metodele au fost armonizate cu interpretările propuse de DCA 60/2000/CE pentru a avea o evaluare unitară a impactului antropic asupra corpurilor de apă şi pentru a sincroniza rezultatele obţinute cu noua metodă propusă prin acest proiect (Indicele de Corespondenţă Taxonomică-ICT). Materialele folosite în această cercetare sunt reprezentate de probe recoltate pentru realizarea determinărilor fizico-chimice, biologice şi bacteriologice respectându-se tehnica de prelevare şi analiză în conformitate cu normativele în vigoare. Metodele pentru evaluarea impactului antropic utilizând parametrii biologici au fost reprezentate de curăţenia relativă (C%), impurificarea relativă (I%), metoda indicelui saprob (S), metoda deficitului de specii şi metoda indicelui EPTT (*Ephemeroptera, Plechoptera, Trichoptera*, grupuri cu specii sensibile la impactul antropic).

Cuvinte cheie: corp de apă, impact antropic, biocenoze acvatice, lucrări hidrotehnice.

INTRODUCTION

The severe alteration of the environment in the last century puts the decision-making factors in the field of water, air and soil management to a hard test to find solutions to improve their quality. In this context, the modern guidelines in the management of water resources follow the direction of ecological rehabilitation of rivers and lakes, with the aim of achieving the environmental objectives: good ecological status for natural water bodies and a good ecological potential for heavily modified and artificial water bodies (CIOBOIU & BREZEANU, 2012).

The methods of evaluating the anthropogenic impact on aquatic ecosystems are extremely varied, as this work focuses on those that use the biological indicators of water quality, namely the relative cleanliness and the saprobic index, which are based on the saprobial system. Other methods use physico-chemical indicators as a criterion for evaluating water quality, such as the water quality index (ICA) or the global pollution index (GI).

Recent studies bring into discussion, for the assessment of water quality, the integral index – an index of total toxicity, which allows researchers to classify water in different categories, from safe to extremely dangerous (MILMAN et al., 2012).

There are researchers who only prefer a group of indicator species as a biological indicator, for example diatoms, which are species that appear in many bodies of water, starting with very cold regions such as Siberia (KULIKOVSKIY et al., 2010) and to areas with higher temperatures.

MATERIALS AND METHODS

The materials used in this research are samples collected for physico-chemical and biological determinations, respecting the sampling and analysis technique in accordance with the regulations in force. The analyses were carried out within the specialized laboratories in the field of water management and the University of Petroșani.

The methods for evaluating the anthropogenic impact using biological parameters were represented by the relative cleanliness (C), relative impurity (I), the saprobic index method (S) and the Ephemeroptera, Plechoptera, Trichoptera (EPTT) index method, considered taxa sensitive to anthropogenic impact (BREZEANU & CIOBOIU, 2003; DUDĂU et al., 2011).

NATURAL FRAMEWORK

The Jiu River is formed in the northern area of Oltenia, near Petroșani, and its reception basin is considered a hydrographic basin of the first order (cadastral code VII-I). The Jiu River has the following characteristics: length 339 km; upstream altitude +1720 m; downstream elevation +26 m; basin area 10080 km2; forest fund area 337710 ha; local slope 0.8 %; sinuosity coefficient 1.85. According to the management plans on the river basin level, 175 surface water bodies, 152 for rivers and 23 lake water bodies (14 natural lake water bodies and 9 accumulations) have been designated (Fig. 1).

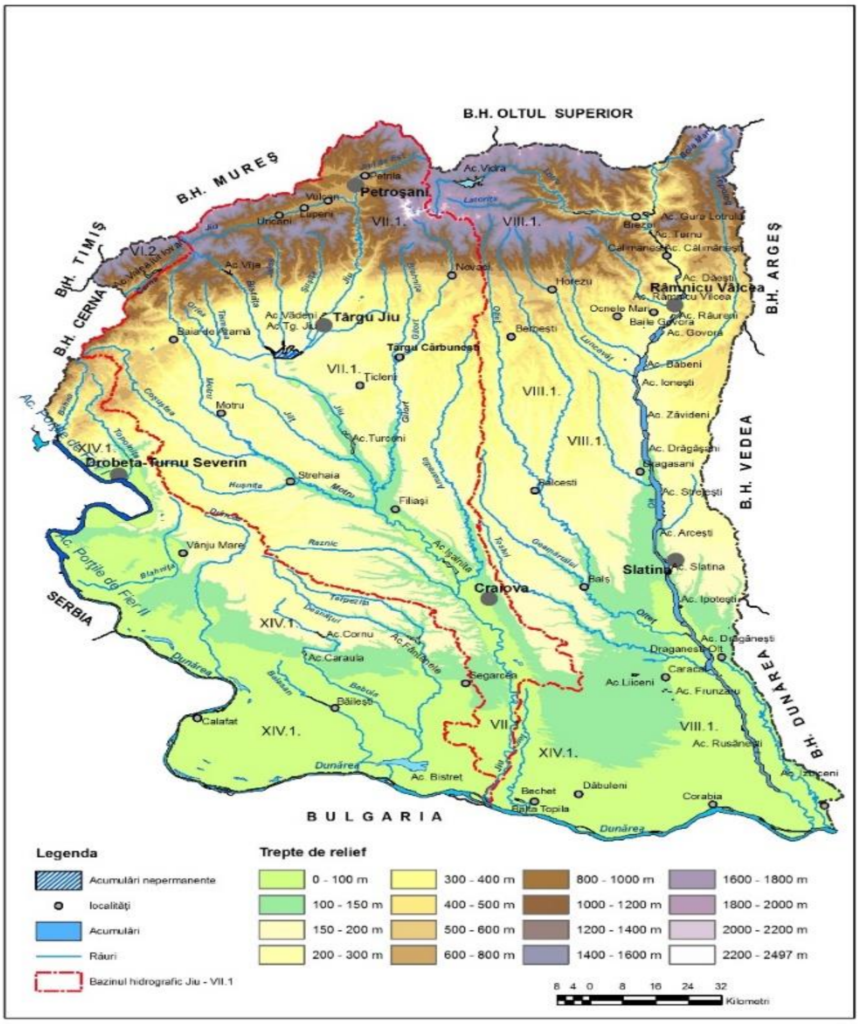

Figure 1. The Jiu River Basin - framing in Oltenia region (after SAVIN, 2010).

1. General description of the riparian zone

The watershed of the Jiu River is located in the south-west part of Romania between 43°45' - 45º30' north latitude and 22º34' - 24o10' east longitude. Its limits are: to the north, the high heights of the Şurian, Parâng, Retezat, Cerna mountains, which separate it from the Mureş, Sebeş, Streiului and Cerna Mureş tributary basins; to the west, the high peaks of the hills and platforms, up to close to the village of Sărbătoarea, and further in the plain by the line of Sărbătoarea - Segarcea - Măceșu delimiting it from those of Cerna - Dunăre, Bahnea, Topolniţa, Blahniţa and Desnăţuiului. To East, the border of the Jiu basin follows a narrow ridge that separates it from that of Olt, until near Craiova, and to the South, the Jiu enters the Romanian Plain, where the border is formed by the course of the Danube River (Jiu Basin Management Plan, Report 2004, retrieved 2009).

The general direction of flow is from north to south and from the slopes to the minor Jiu River bed. Regarding the flow, the major influence of the area adjacent to the Jiu River can be observed, namely the feeding of the water table from the Jiu River during periods of high rainfall, when the river flow is high, and the exchange of water from the aquifer to the river, during dry periods. From a geological point of view, the studied area belongs to the Wallachian Platform structural unit (Moesic Domain). At the surface of the land, we find unconsolidated Quaternary age deposits (Upper Holocene), composed mainly of sands and gravels and subordinately of dusts, which represent the deposits of the low terrace of the Jiu River. The arrangement of the sediments of the low terrace of Jiu River is quasi-horizontal (slopes around 1%0).

The relief and soils. The Jiu River crosses the landforms specific to Romania: the mountain area, the subcarpathian arc, the piedmont area and the plain area (Fig. 2). In relation to the altitude, over 21% of the catchment area, namely the northern and northeastern parts, are occupied by mountain areas. The hills belonging to the Getic Piedmont represent 47%, with the plain area occupying over 32%. This layering of the relief on a large difference in level, from 2159 m (Vf. Mândra Munţii Parâng), to 24.1 m (the confluence of Jiu River with the Danube River) reflects the diversity of relief forms. In this sense we mention: Retezat Mountains, Godeanu Mountains, Şurianu Mountains, Vâlcan Mountains and Parâng Mountains.

The Oltenia Plain is the result of the influence of the Danube, the predominant forms of relief being represented by terraces, meadows and sand dunes. In the confluence area of the Jiu River with the Danube, terraces are approximately 10-12 km wide, and later become narrower (DUDĂU, 2004a; b).

The meadow relief – in particular, the Jiului Meadow in the confluence area with the Danube – is one of the most developed meadows of the inland rivers. It is 3-6 km wide, the river has high banks to the west (15-20m), and, due to the tendency of continuous movement in this direction, the right bank of the Jiu is permanently eroded, most of the meadow remaining on the left side. Both near the Danube and the Jiu, on their lower terraces, there are sometimes high dunes, such as those in the Bechet and Lişteava areas, located in sites of avifaunistic importance (COTEŢ, 1975).

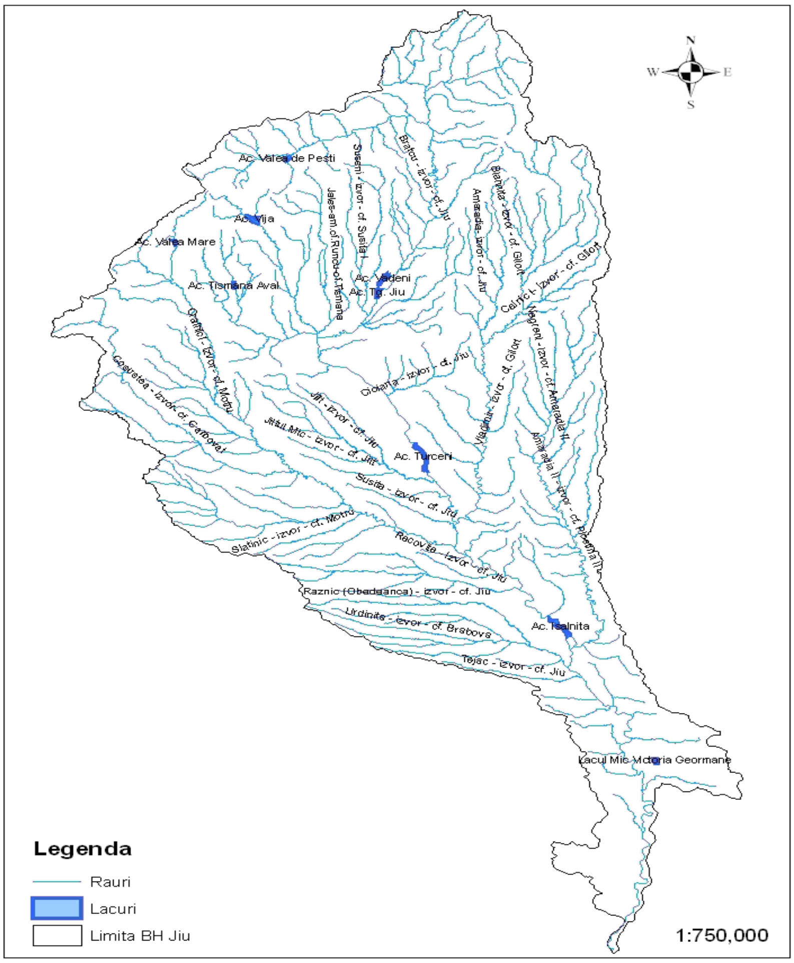

Figure 2. The hydrographic network in BH Jiu (original).

Soil is the result of the action of external factors on the earth's crust. Skeletal and podzolic soils (in the mountainous area), reddish brown forest soils, brown podzolic soils (in the region of the Getic Piedmont and the low plateaus), chernozems and sandy soils (in the large meadows of large rivers) are identified on large basin areas under which strong water tables can be found (SAVIN, 2008).

The multiannual average stock of the Jiu River, in the Zăval section (upstream of the confluence with Danube River) is 2762.5 million m3. The recording of underground water resources at the level of territorial units of water management was imposed by the need to perform their management, by their integrated management with those of the surface, as well as by the adoption of a policy of preferential allocation (SAVIN, 2008).

2. Significant pressures in the Jiu Hydrographic Basin

For the most part, the Jiu river basin overlaps with the coal basin of Jiu Valley, it is part of the historical Oltenia region and is known in the country for its coal deposits (from the Jiu Valley/upper basin of BH Jiu) and the lignite deposits in the Middle basin of Jiu River, which is why, in the pre-December period, open-pit mining in Gorj County and underground mining in the Petroşanilor Depression experienced a great development. Due to the hydro-energetic potential of the Jiu River and the coal deposits in the region, there are more thermo-electric power plants on the riverbank than in other areas, the most important being Paroșeni (coal), Rovinari, Turceni, CET I-Ișalnița and CET II-Craiova (lignite).

It is known that approximately 30% of the national energy production is produced in the basin of the Jiu River. There are also oil fields in the vicinity of the Jiului Meadow (e.g. Stoina or Răcari), and PETROM SA has announced a gas discovery with significant potential in southwest Romania. The discovery was made with the help of the 4539 Totea exploration well, which drilled in the Oltenia region, at a depth of 3,600 meters. With these pressures exerted by the exploitation of natural resources, the existence of human settlements must also be taken into account, such as the large cities (Petroşani, Târgu-Jiu, Craiova), a series of localities. The hydro-morphological alterations that have additionally resulted in the modification of the morphology of rivers for energy purposes, represent significant long-term pressure on the aquatic ecosystems, because the hydrotechnical works with transverse barriers (dams, bottom thresholds) interrupt the longitudinal and transverse connectivity of rivers, which affects the hydrological regime of rivers, the relationship with the adjacent wetlands, the transport of sediments and, last but not least, the migration of the fish fauna. These effects are the result of hydrotechnical works (dams, bottom thresholds), works that were not provided with fish ladders for the migration of ichthyofauna and which result in the specific impoverishment of aquatic biocenoses, as well as the clogging of accumulations (most often with suspensions from mining activity) and small water catchments (Fig. 3).

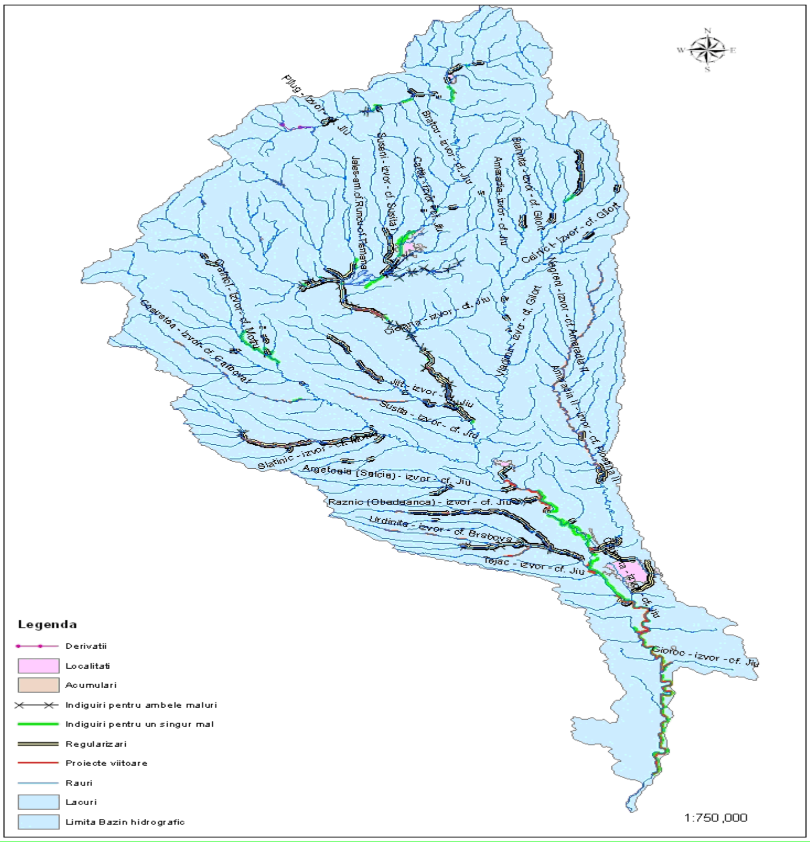

Figure 3. The main hydrotechnical works in Jiu Hydrographic Basin (original).

The works along the river (dams, regularization, etc.) have a significant negative impact on the lateral connectivity of water bodies, i.e. on their connection with the floodplain of the rivers. This affects the reproductive migration of cyprinid species, reducing their natural population and causing the decrease of other forms of biodiversity, with the aridization and sometimes desertification of riparian zones (for example, Dăbuleni-Călăraşi area in Dolj county). Hydrotechnical works were created in the Jiu BH for defense against floods, to support the regional industry (in the case of Jiu River for energy production) and finally, to supply drinking water to the big cities. All these constructions have significantly changed the Jiu River in terms of morphology (by regularization, dyking, damming – Fig. 4.3), in terms of hydrology (modification of natural flows as a result of water withdrawals and returns for industrial and drinking purposes), from a biocenotic point of view (the transformation of river into a reservoir), from the point of view of the thermal regime of the water, as the temperature has increased by approximately 10ºC on average (according to ISSWaP, 2010) downstream of the evacuations of energy complexes. The middle basin of the Jiu River is the area with the most anthropogenic pressures, exerted both on surface and on underground waters. There are pressures of a chemical nature (point sources), coming from industry, but also diffuse sources, represented by the lack of centralized sewage and purification systems in small towns, not yet connected to the sewage and agricultural systems.

To support what was presented previously, I will list the pressures that are permanently maintained on the surface and underground water bodies in the middle basin of the Jiu River, extremely varied pressures that have a negative impact on the ecosystems, thus (according to ADLER et.al., 2010):

- the current mining operations are quantitatively affecting the groundwater body ROJI05 - Jiu riverbank and terraces;
- thermal power plants and industrial zones increase air and soil pollution with a wide variety of substances, starting with heavy metals, but also with various sulphur or nitrogen compounds, increasing diffuse pollution in the area;
- slag and ash dumps increase groundwater pollution through permanent infiltrations where there are cracks and incorrect waterproofing;
- large cities evacuate insufficiently purified wastewater, and in their area, the underground water is also polluted with nutrients;
- agriculture is still a diffuse source of pollution through the uncontrolled use of fertilizers and pesticides;
- the hydrographic network is permanently affected from a quantitative point of view due to the existing uses on the water bodies of the Jiu River;
- aquatic and terrestrial ecosystems may suffer through the reduction of habitats and through the quantitative reduction of water resources.

3. Biomonitoring in the Jiu River Basin

In order to characterize the state of surface waters in any hydrographic basin, including the Jiu Hydrographic Basin, the Water Framework Directive 2000/60/EC imposes the biological quality elements required to characterize the ecological state, as follows:

• surface waters-rivers: composition and abundance of aquatic flora; the composition and abundance of the benthic invertebrate fauna; the composition, abundance and age structure of the fish fauna;

• surface waters-lakes: composition, abundance and biomass of phytoplankton; the composition and abundance of aquatic flora; the composition and abundance of the benthic invertebrate fauna; the composition, abundance and age structure of the fish fauna (CIOBOIU, 2002; 2003; DUDĂU, 2010a; b; c).

For follow-up monitoring, DC 2000/60/EC proposes the frequencies given in the table below.

Table 1. The main biological quality parameters and their monitoring frequency (according to DCA 60/2000/EC).

The biological element of quality	**The frequency of monitoring biological parameters for rivers**	**The frequency of monitoring biological parameters for lakes**
Phytoplankton	1/6 months	1/6 months
Phytobenthos	1/6 months	1/6 months
Other aquatic flora (macrophytes)	1/3 years	1/3 years
Benthic invertebrates (macrozoobenthos)	1/3 years	1/3 years
Fish	1/3 years	1/3 years

4. Evaluation of the impact of hydrotechnical works on aquatic ecosystems

The methods used for assessing the anthropogenic impact using biological parameters were relative cleaning (C%), the relative impurification index (I%), saprobic index method (S), the TPET index method (*Ephemeroptera, Plechoptera, Trichoptera* – groups of the susceptible species to anthropic impact). To assess the anthropic impact using physicochemical indicators, the following were applied: the water quality index method (WQI), the global pollution index (GPI). For the water quality index method (WQI) bacteriological data were used additionallyfor each investigated water body. Results and interpretations: the methods have been harmonized with the proposed interpretations of the Framework Water Directive 2000/60/EC, in order to have a unitary evaluation of anthropogenic impact on water bodies (Figs 4.1; 4.2; 4.3).

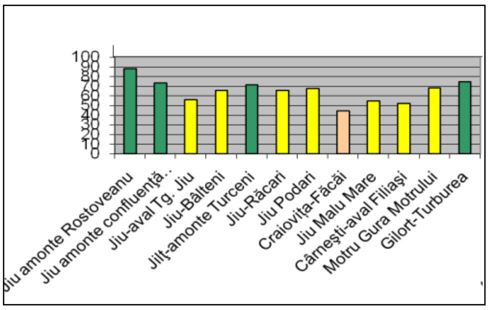

Figure 4.1 WQI variation for the Jiu river and its main tributaries-2018.

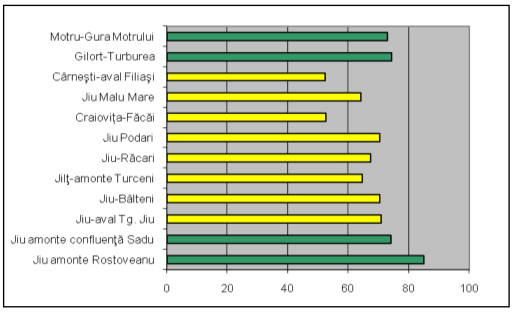

Figure 4.2 WQI variation for the Jiu river and its main tributaries-2019.

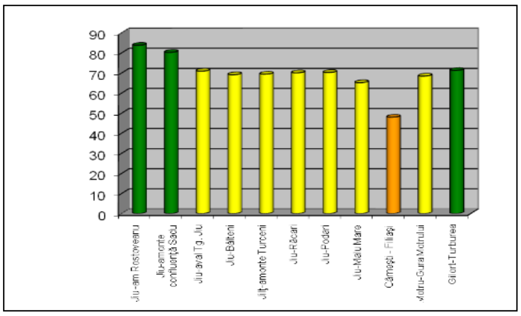

Figure 4.3 WQI variation for the Jiu river and its main tributaries-2020.

As shown in the previous charts, the water quality of the researched water bodies according to the WQI is in good and moderate ecological status (for 2018-2020 period). In 2018 and 2020, the rivers Craiovița and Cârnești had poor water quality. The Global Impact Index -GI (Figs. 4.4 - 4.9) was calculated for 2018 for the most important monitored stations on the Jiu river (CIOBOIU & BREZEANU, 2002; CIOBOIU & CISMAȘIU, 2018).

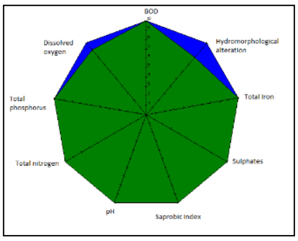

Figure 4.4 Global Pollution Impact Index- Jiu river confluence

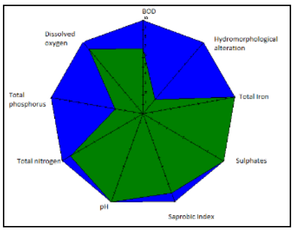

Figure 4.5 Global Pollution Impact Index for the Jiu, upstream Sadu downstream Târgu Jiu

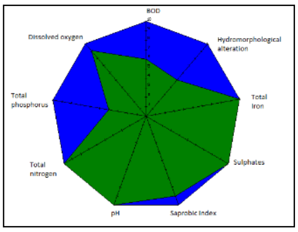

Figure 4.6 Global Pollution Impact Index for the Jiu river, Bâlteni

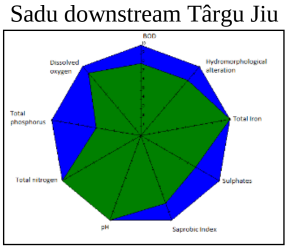

Figure 4.7 Global Pollution Impact Index for the Jiu, Răcari

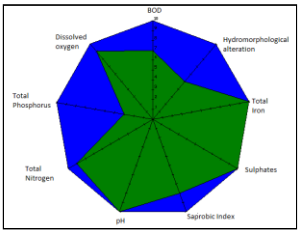

Figure 4.8 Global Impact Index for the Jiu - Podari

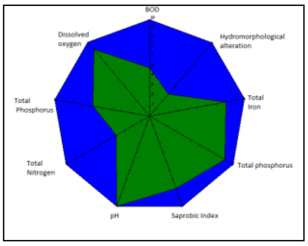

Figure 4.9 Global Impact Index for the Jiu – Malu Mare

Except for the Malu Mare section, where the aquatic ecosystem is subjected to anthropogenic activity, causing an uncomfortable status of the life forms (GPI = 2.11), the other monitoring stations correspond to an environment under anthropogenic activity within acceptable limits (GI between 1,07-1,72) (Table 2).

Table 2. Comparison of the results achieved by applying the various indices to assess of the anthropogenic impact on the Jiu water body along the Târgu Jiu-Craiova sector.

No.	Monitoring stations For the Jiu water body, Targu Jiu-Craiova sector	Evaluation of the antropic impact on the water ecosystem using the biological indicators (water quality class)			Evaluation of the antropic impact on the water ecosystem using the biological indicators (water quality class)	
		C%	**Saprobe Index**	**TPET%**	**WQI**	**GI**
1	Jiu upstream the Sadu confluence	II	II	II	II	II
2	Jiu downstream the Târgu Jiu reservoir	II	II	III	III	II
3	Jiu Bâlteni	II	II	III	III	II
4	Jiu Răcari	II	II	III	III	II
5	Jiu Işalniţa	II	II	III	III	II
6	Jiu Podari	II	II	III	III	II
7	Jiu Malu-Mare	II	II	III	III	III

CONCLUSIONS

At this moment, from the point of view of the mining activity for the Jiu river basin, the current mining operations in Gorj county continue to represent an important pressure with a significantly negative impact on the terrestrial ecosystems, less so on the lotic and lentic aquatic biocenoses. Diffuse pollution due to tailings dumps and slag and ash dumps in the immediate vicinity of large energy complexes (charges of groundwater with sulfates, with heavy metals, increases in water conductivity), as well as thermal pollution in the middle sector of Jiului, downstream of the evacuations from CE Rovinari and CE Turceni, add to this pressure.

The research led to another conclusion, that the underground water annually receives increased amounts of pollutants from the group of toxic substances that alter the biotope, as shown by the fact that the meadow and terraces of Jiului (underground water body ROJI05) is declared at risk for nitrate pollution. It should be mentioned that the natural background for this body of underground water is qualitatively affected, it presents important loads of nutrients from agriculture.

Other significant pressures in the middle basin of the Jiu River are represented by the hydro-morphological alterations resulting from hydrotechnical constructions (Târgu Jiu and Vădeni reservoir dams, Işalniţa reservoir dam, dams on more than half the length of the water body, thresholds or bank regularization). Although these have the role of defense against floods, the role of water reservoirs for various uses (for example industry, agriculture, drinking water), they also had negative effects because they retained a large part of the pollutants, they reduced the connection of the Jiu River to the point of cancellation with its flooded meadow, by cutting the old meanders and by regularizing the bank. The rehabilitation of these ecosystems can be achieved through a single type of project - the restoration of wetlands, which has been presented and described in other works by the authors.

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