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Identifying Problems of the Danube Ecohydrology in the Iron Gates Reservoir Area

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Abstract
The present paper underlines the fact that a sustainable water resources management should look into the interdependence between hydrological and ecological characteristics of a specific area and not only the hydrological features. The concept is supported by the study case of the Danube reach, whose liquid and sediments flows are controlled by the Iron Gates I and II Reservoirs. The hydrological parameters and ecological features of the Danube reach, before and after impounding, are presented, as well as the eco hydrological problems occurred during operation of the reservoirs. Solutions to some of the problems are offered.
Keywords: ecohydrology, alluvial terraces, aquatic organisms.

1. INTRODUCTION

The Iron Gates reservoir area includes the hydro energetic and navigation system: Iron Gates I (942+950 km on Danube) and Iron Gates II (80 Ian downstream) with the channel of the river and the auxiliary ecosystems (sectors of tributary rivers, floodable area and springs). The relief of the area is represented by the massifs of the Iron Gates Carpathians (up to 1560 meters high) surrounded limestone depressions.

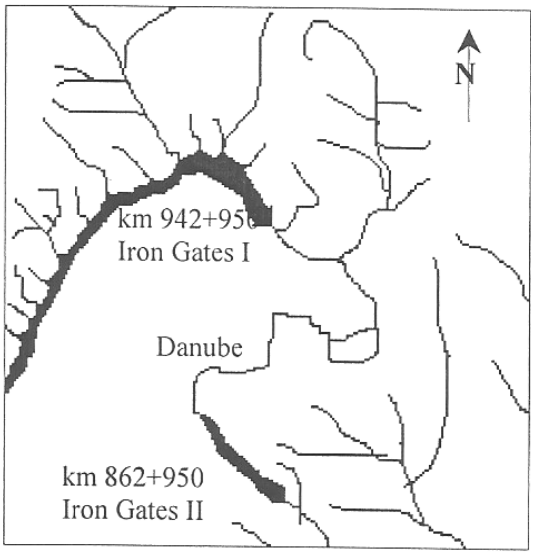

Figure 1. The Iron Gates Reservoirs System

The Danube Valley is characterized by a morphological asymmetry: the left bank is high and steep while the right bank is low.

Hydro geologically speaking, one can notice the presence of permeable rocks and an underground water flow drained indirectly through tributary valleys and directly to the Danube Delta.

2. HYDROLOGICAL CHARACTERISTICS OF THE DANUBE SECTOR

The value of the multi annual average flow on the Danube in the Iron Gates I is $Q_n = 5420\ m^3\ s^{-1}$.
The maximum flows with 0.1%, 1% and 10% probability have values between 19300 m^3/s, 16350 m^3/s, respectively 13000 m^3/s. These are registered in April - June period due to snow melting and storms, as well as at the end of November or in December.

The minimum flows registered in the rest of the year are 1460 m^3/s , 1320 m^3 /s, respectively 1100 m^3/s with 90%, 95%, 99% certainty.

In winter, this sector displays characteristics that are different from other Danube sectors because the morphology of the river bed has unique aspects: local zones having slopes that are higher (2.20 m km^{-1}) than the average of the entire river (0.24 m km^{-1}) and even of the Superior Danube (0.40 m km^{-1}); riverbed widths between 150 m and 1200 m. The water flow is turbulent, with ice formation.

The water flow regime in the Iron Gates area is greatly modified by the damming:
- upstream Iron Gates dam, the conditions created by the damming impose slow speed of water stream (1 m S-I in modified regime as compared to 5 m S-I in natural regime);
- the influence limit of the backwater reservoir reaches Tisa confluence (km 1214+500); the accumulation volume is approximately 1.0 - 1.5 % from the multiannual average stock of the Danube (174xl0^9 cubic meter);
- downstream one can notice an oscillating regime of flows and levels due to the operations of the Iron Gates I and II power stations according to water flow.

The Iron Gates II Reservoir has greatly improved the regime of downstream water flow resembling the natural regime.

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A particular phenomenon in the dam sector is the formation of wind and navigation waves leading to bank erosion. The presence of reservoirs has changed the hydro geological regime, too. The alluvial terrace zones and alluvial cones, in which there were phreatic layers, have been covered due to the flooding of the low land. The water level in wells has grown and the drinking water resources have been reduced.

2.1 THE ALLUVIAL TRANSPORT

The regime of the solid flows is the most important component of the natural flow regime. It has been greatly modified and has negative effects on the entire course of the Danube, including the dynamic equilibrium of the beaches on the Black Sea shore.

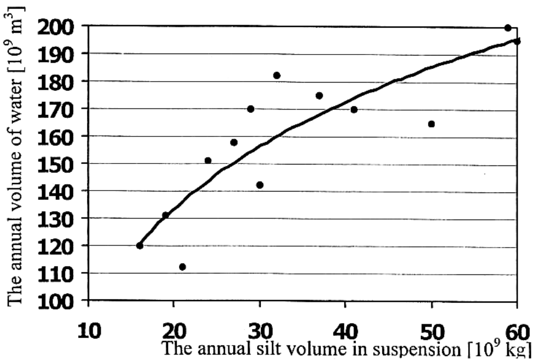

Figure 2. The correlation between liquid and silt flow in natural regime on the Danube River in Iron Gates reach

In the natural regime the alluvial deposit flow on the Danube in the Iron Gates area was about $35x10^9$ kg an^{-1}. There is a well-defined relation (Fig. 2) between the liquid flow and the solid one, which is characteristic of large catchments areas (S=576230 km^2).

The flow of the dragged alluvial deposit is below 1% of the solid suspension flow. After the construction of the Iron Gates I reservoir, the alluvial deposit flow has decreased by 70 - 80 % in the first years of operation. Later, due to the interference of the Iron Gates II the alluvial deposit flow has increased, yet insignificantly.

The increase in the basic level of the brooks and torrents situated upstream the dam, has led to the modification of the suspension depositing areas. Sediment depositing occurred in the areas of the dam with slow speed water.

The deposits (below $300x10^6$ m^3) are distributed irregularly along the basin. In the area where the Danube reaches Romania, the clogging phenomenon is absent; the biggest deposits are noticed between km 1004 and 970, decreasing towards the dam.

It has been noticed a slow down in the clogging phenomenon lately.

The deficit of alluvial deposits at the flowing of the river into the sea has amplified the difference between land and water along the Romanian Coast.

2.3 THE ECOLOGICAL CHARACTERISTICS OF THE IRON GATES AREA

The research carried out in the Iron Gates area before dam construction, revealed the new conditions that brought about changes in the fauna and flora of the area, positive and negative aspects from an ecological point of view.

Due to the increase in water level and auxiliary flooding zone, the structure of the biocoenosis, flora and fauna have been greatly modified. Under the new environment circumstances, some species have disappeared (those specific to the flooded areas), others have reduced their spreading area (especially fish species), while others have spread rapidly becoming dominant in the ecological configuration of the ecosystem.

The modifications occurred in the biotype have affected some economically and ecologically important fish species which fed themselves and mated here (e.g. starlet, sturgeon) or were in transit moving towards river upstream (e.g. herring, sturgeon).

From the perspective of physical-chemical factors, there have been significant biotype changes after the construction of the dam. One can notice an area in the central of the lake whose physical-chemical features resemble those of the river and tributary bays. The chemistry of the Danube waters in the Iron Gates area is strongly influenced by the area pollution (coal mining, wastewater discharge), the concentration of metals such as Zn, Cd, As, Hg exceeds accepted norms. Both reservoirs retain sediments with heavy metals limiting Danube pollution over a longer sector.

Previous to the basin construction, water self-cleaning on the sector upstream the Iron Gates I was performed, the Danube waters in this area being considered the standard of the natural state from a physical-chemical point of view.

Reservoirs slow down the self-cleaning process, since aeration is weaker in the natural regime.

3. INTERDEPENDENCE OF HYDROLOGICAL AND ECOLOGICAL CHARACTERISTICS. CONCLUSIONS

The blocking of the Danube river bed in the Iron Gates area and the consequent increase in the water level have radically and irreversibly changed the previous characteristics as well as influenced the hydrological and ecological - characteristics along a sector of more than 100 km. While, before dam construction, the flooding occurred during high water having variable intensity and duration, now it is determined by power station operation. Level variations of about 2-3 m at the dam determine water flow tide and ebb tide which are stronger felt in the reservoir low areas having direct consequences on the biology of this area. An important hydrological feature influencing the ecological regime of the reservoir is the speed of water flow which decreased 4-5 times, while in some parts (bays and low areas) is almost absent. Consequently, the amount of suspension substance decreased about the same times, whereas water transparence increased 3- 4 times.

The modification of the Danube hydrological regime due to dam and reservoir construction has brought about changes in the lotic biotope. Unlike the Iron Gates I reservoir which belongs to the category of river-lacustrian aquatic ecosystems, the Iron Gates II is a fluviatil reservoir in which ecological functions and structures are quite similar to reophile ecosystems. A lot of the fauna and flora species have disappeared, certain species have adapted while others, a reduced number, have evolved becoming dominant.

The biotic processes of the aquatic ecosystems have a dynamic characteristic and are influenced by the hydrological and polluting factors. Consequently, the models for water quality need to describe and quantify the main biocoenotic relations in connection with abiotic factors (hydrological, climatic, physical-chemical factors).

The state of water quality is rendered and determined by the biological processes, too. Bacterium play an important role in the carbon, nitrogen and phosphorus cycles, algae are also involved in the nutrient dynamics and generate organic matter which, under the circumstances of advanced eutrophication, becomes an ecological disaster factor, with negative consequences on water quality.

With a view to achieving a fair model and a true picture of the ecosystems' evolution, it is necessary to keep observing the structure of the populations of invertebrate and vertebrate animals in relation to the primary producers (algae, macrophytes).

The forecast of anthropic activity and ecological and water quality management is dependent on the one-dimensional biocoenotic models.

When quantifying the situations with varied flood tides, the use of non-stationary models is considered to be necessary. Under the circumstances of process modeling with still waters (e.g. the Iron Gates I reservoir) one can use bio-dimensional models since long spans of water retaining in still zones cause a higher degree of plankton biocoenoses development as compared to the reophile sectors of the river-lacustrian ecosystem.

The switch from one-dimensional models to multidimensional ones can provide complex information, but increase the risk of amplifying relatives.

The most feasible solutions impose the use of models for which it is necessary to determine essential parameters, which influence the relevant processes.

It is important to set up a complex research program to monitor process development with a view to establishing methods and means for environment protection and efficient use of natural resources.

The paper attempts to point out the positive and negative effects of the Iron Gates reservoirs on the environment from the perspective of qualitative ecohydrological co-relations. Consequently, the presence of the reservoirs has had the following consequences on the biocoenotic structures and populations of animals, and plants:

- a positive effect involving diversity of biocoenotic structures, development of new ones, increase in the useful biological production through the formation of lacustrian ecosystems
- a negative effect involving destruction of terrestrial ecosystems (by flooding) ecological disaster caused by extinction of certain species of plants and animals, depreciation of rheophile biocoenoses, occurrence of eutrophication phenomena in the reservoir. It is worth noticing that the phytoplankton has greatly developed (about 5 times), the zooplankton has decreased in terms of species number but increased in terms of density and weight, whereas ichtyofauna has decreased in terms of species number (Table 1).

Table 1 – The qualitative evaluation of the impact on environment matrix

	Water usage				Works					Actions and improvement works			
Code	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Actions / Effects	Energy production	Navigation	Pisces culture	Tourism	The dam and added buildings	Dykes and bank protection works	Clearing works	Quarries	Electric lines	Detours of railway and roads	Shifted localityes	Torrents works	Forced exploitations of the reservoir
Socio-economical													
Energy production	+++				+++					++			+
Navigation		+++			+++								
Pisces culture			-		-								
Tourism				++	++	++					+	+	
Land Expropriation						-	+		-		-	-	
Cultural Patrimony						-	+					-	
Water distribution					-	-							
Landscape					+++	+++			-	-	+	+	
Others					++		+		+	+	+	+	
Geo-physical													
Morphology (silt transport)	---	-			--	--					-	+	---
Erosion	++	-		-	--			-				+	---
Silt deposits					---	--							
Black Sea coast stability	---			--	--	--							
Drainages	-					-	-				-		
Relationship with Bulgaria	--	-											
On the ecosystems													
Micro-flora					-	-							
Macro-flora													
Phytoplankton		-			+	+							-
Macro-fauna													
Fish			-		-	-							
Zooplankton		-			+	+							-
Rare species			--	-	--								

Legend:	Positive	Negative	
	+++	---	Very strong effect
	++	--	Medium effect
	+	-	Weak effect

One can also achieve a direct / indirect cost assessment of the effects of parameter interdependence.

Table 2 – Costs evaluation matrix

Action / Effect	1	2	3	...	*i*	...	*n*
1							
2							
3							
...							
j					$p_{ij}C_{ij}$		
...							
m							

p_{ij} — weight coefficient (p =1 ...10)

The integral effect of the *i* action is:

$$E_i = \sum_{j=1}^{m} p_{ij} \cdot C_{ij} \quad (1)$$

Where: i-constant 1, 2, 3 …, n

j-1, 2, 3, ………………, m

Simultaneously the relation gives a certain j effect determined by the overlapping of the exerted actions:

$$E_j = \sum_{i=1}^{n} p_{ij \cdot C_{ij}} \quad (2)$$

Where: j-constant 1, 2, 3 …, m
i-1, 2, 3, ………………, n

The global effect of the actions exerted by the analyzed reservoirs can be assessed through the cumulated costs:

$$E_j = \sum_{i=1}^{n} \sum_{i=1}^{m} p_{ij \cdot C_{ij}}$$

Where: j - 1, 2, 3 …, m
i -1, 2, 3…, n

For the different solutions to modify the negative effects alternatives / corresponding costs are established and this allows the choice for an economically optimal option.

Phenomena quantification based on qualitative analysis through subsequent elaboration of theoretical computing models will facilitate ecosystem evolution assessment for a lasting ecological management of water resources and adoption of solutions for some of the problems mentioned in the paper.

Proceeding the ecohydrological research within the PHI-VI (Action 3) is welcome and necessary as it involves the use of an already existent diverse database as well as data from a complex analysis of the Danube water quality carried out along the entire length of the river by the International Commission for the Danube River Protection (August-September 2001 expedition).

Romanian researchers in the field of ecohydrology have joined forces in a team work to outline a program meant to capitalize on their accomplishments, without overlooking exchange of opinions with foreign researchers (Ecohydrology Project within PHI-V UNESCO) in view of a long term approach to eco hydrology -related Issues.

Besides global theoretical study approach, aiming at in time-monitoring of hydrological and ecological processes, one should not overlook specific regional problems (case studies) having general implications:

- biocoenotic model-based quantification of the interdependence of hydrological and ecological parameters on the Danube river in the area of the Iron Gates reservoirs
- connections among the Danube branches in the Delta area and lacustrian area in terms of ecohydrology, water circulation, ecological state of inland area
- determining characteristic reservoir indicators (refreshment, eutrophication indicators) by co-relating water regime with bio-diversity spectrum.
- the study of ecohydrological processes specific to mountain area in terms of cause-effect relations which determines their hydrological, biological dynamics and interdependence.
- Researchers support the setting up of a Center for Ecohydrological Studies in Timisoara - Herculane, Romania, a representative ecohydrological reservoir in the Cerna hydrographical reservoir, as well as extending the hydrological monitoring to an ec hydrological one, once the necessary equipment is made available).

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