3rd International Conference on Energy and Environment CIEM 2007, Bucharest, 22-23 November

HYDRO-ENERGY PRODUCTION AND WATER WORKS FACE TO FACE WITH " ENVIRONMENTAL FLOW APPROACH" IN ROMANIA

By Neculai Mihailescu*, Aurel Varduca*, Liviu N. Popescu*, Ioana Cristina Varduca*

Abstract

In order to make an equilibrium between the need of "environmental flow" and the other needs like energy in this case studies are presented in the paper: (i) iron Gate Hydro-energetical complex in the lower Danube river and (ii) Dambovita river complex hydrotehnical works within and downstream Bucharest. For the first use the most relevant impacts are related with: (i) nutrient "pump" particular properties; (ii) contamination of sediments with heavy metals and other associated pollutants; (iii) decrease of solid (suspended matter) loads – hydromorphological alterations (iv) cutting the fish migration and other related issues. In the second case study the environmental flow practically do not exist. The Dambovita river downstream of Bucharest face the increased organic loads, nitrates and especially with hazardous substances contamination.

Keywords: Water Framework Directive, nutrients, heavy metals, impact, eutrophication, hydroelectricity

1. Introduction

The International Commision for the Danube River protection Convention Expert Groups (ICPDR – EG) generated in 2004-Roof report Part A, where for the implementation of the Water Framework Directive 2000/60/EC four main pressures were identified: (i) organic pollution, (ii) nutrients pollution, (iii) hazardous substances and (iv) hydromorphological alteration. The pressure (iv) is generated by waterworks (dams, reservoirs, dikes, water courses regulation etc). Beside of the longitudinal and lateral connectivity alteration of the "environmental flow", particularly downstream of the hydropower units, has to be (re) considered too [2].

Based on two case studies, iron gats reservoir and Dambovita – Bucharest water work system, the paper presents some of the relevant identified links between hydromorphological alteration and "chemical status" of studied water bodies, in order to obtain a better understanding of the impact consequences, on long term, at the level of affected aquatic ecosystem and downstream of them.

The primary data were obtained using national projects carried out by ICIM and from the ICPDR – transnational Monitoring Network (T.N.M.N) yearbook, ICIM being National reference Laboratory (N.R.L).

* National Research and Development Institute for Environmental Protection – ICIM Bucharest Romania

2. Hydromorphological alteration

Hydrologic connectivity is now widely acknowledged as a fundamental property of al ecosystems, being defined as " Water mediated transfer of matter, energy and organisms within or between elements of the hydrologic cycle". Thus, in rivers, hydrologic connectivity refers to the water-mediated fluxes of material, energy and organisms within and among components, e.g. the channel, flood plain, alluvial aquifer, etc, of ecosystem. This hydrologic connectivity can be viewed as a operating in longitudinal, lateral and vertical dimensions and over time.

Changes in flow regime may restrict longitudinal connectivity in various ways. The physical barriers to migration of fish and other biota imposed by dams and weirs have long been recognized. Beside of these, the reservoirs used for hydropower generation, may have in addition specific impacts such as eutrophication and associated sediment pollution particularly with heavy metals.

3. Environmental flow concern

The environmental flow is contained into the three Es for Integrated Water Resources Management Process (IWRM): **E**conomic Development Social **E**quity and **E**nvironmental Sustainability where: Key concept is the cross – sectoral integration of the four "teeth" of comb: water for people, Water for food, water for nature and water for other users (flood risk management, industry, hydropower, irrigation etc) [4].

Generally it is admitted that the environmental flow should be 25-30% from the inflow, downstream of the dams.

After 2000, in Romania the average annual water allocation for the environmental flow is about 35% - ecological protection purpose – in the national water balance.

4. Iron gate reservoir case study

The selection of this case study was done at least from two reasons: (i) the Cousteau Report (1992) [1] where the sediment associated pollution is characterized as "long term chemical bomb" and (ii) some of the projects carried out in the framework of UNDP-GEF Programme (ICPDR 2000-2005) which present that the Iron Gate reservoir is a "trap of nutrients".

* National Research and Development Institute for Environmental Protection – ICIM Bucharest Romania

4.1. General approach

As a consequence of the large water works carried out during the time (artificial reservoirs, dams, dikes, river regulation, works diversions etc) first of all on the Danube River and secondly at the level of its major tributaries, practically all the Danube River is characterized as :at risk" and "possible at risk" from the hydromorphological alteration point of view (ICPDR – roof report part A – 2004).
For Romania, almost 43% of the water bodies are "at risk "and "possibly at risk", the most relevant pressure being caused by hydromorphological alteration (36.4%) followed by nutrient pollution (19.6%), organic pollution (15%) and hazardous substances 5.7%)[3].

Tab 1.

The ratios between outflow (Gruia) and inflow (Bazias) of the Danube River into Iron Gate reservoir (mean monthly values) – 2005

month	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
m^3/sec Gruia	4400	4540	7570	11090	9420	6130	5860	5720	5690	4810	3100	5590
m^3/sec Bazias	4630	4690	7920	11610	9670	6050	6070	5940	5720	4830	3090	5830
Ratios Gruia / Bazias	0.95	0.97	0.96	0.96	0.97	1.01	0.96	0.96	0.99	0.99	1.00	0.96
Notes: annual mean ration = 0.97 Gruia annual mean flow: 6160 m^3/sec Bazias annual mean flow: 6340 m^3/sec												

For the Iron Gate reservoir selective impact analysis due to hydromorphological alteration – mainly longitudinal connectivity, the following specific characteristics have to be considered:

(i) the ratios between outflow (Gruia hydrological station) and inflow (Bazias hydrological station) is 0.97 (annual mean value) with a range between 0.95-1.01 (table 1); at least from this point of view there are not any problem in regard with the environmental flow downstream of the dam;

(ii) the ratios between suspended matter concentrations for the above mentioned hydrological stations 92005) are in the range of 0.64…..1.07 with an annual mean value of 0.78; however, because of the backflow form iron gate, the suspended matter concentration decreased from 55 mg/l (Borovo station Km 1337) to 28 mg/l (Pristol Novoselo station Km 834) – TNMN

* National Research and Development Institute for Environmental Protection – ICIM Bucharest Romania

Yearbook 2003; this is equivalent with 49% retention capacity of suspended matter in the above mentioned Danube River stretch.

(iii) disruption of the river continuum, with all the negative consequences for fish migration is obvious but should be analysed at the Danube River basin wide, where, upstream of Iron gate there are more than 50 dams.

(iv) disruption of the sediment transport is a result of (ii) and (iii) but with a higher weight of (iii).

As an overall, in regard with the longitudinal connectivity Iron gate reservoir should be considered as the most relevant example of hydromorphological alteration but just one of the causes which has to be integrated with other upstream water works which determine as a whole, the characterization of the middle and the downstream part of the Danube River as a heavily modified water body.

(v) protection of ecosystem and flora and fauna has to be related with a detailed analysis of the eutrophication potential and sediment associated pollution, both of these being connected with the upstream long term influx into the Iron Gate Reservoir.

Two type of analysis were carried out in this regard: first based on the output / input concentration assessment and second using the output/input load fluxes appraisal.

4.2. Eutrophication issues

For the concentration approach the regression curves $C_{out} = f(C_{in})$ of the eutrophication indicators were established (table 2).

Tab 2.

Correlation between concentrations (Gruia/Bazias) 2005

Indicator	**ECUATION**	R^2
$P\text{-}PO_4$ mg/l	Y = 0.5166x + 0.0158	0.408
$N\text{-}NO_3$ mg/l	Y = 0.2785x + 0.7434	0.3938
$N\text{-}NH_4$ mg/l	Y = 0.8986x + 0.0299	0.3517
Chlorophyll a µg/l	Y = 1.0965x – 0.4549	0.96

As it can be see, expressed in terms of concentration the nutrient trap correspond with a decrease of 19.6 % of $N – NO_3$, 33.3% of $P\text{-}PO_4$ (limiting factor) and with 28.7% for $N\text{-}NH_4$, in parallel with an increase of 5.8% in the case of chlorophyll a (mean annual values with higher values during the summer time). It has to be noted that the ratios $N\text{-}NO_3$ / $P\text{-}PO_4$ (annual mean values) are increasing from

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Bazias (14.54) to Gruia (18.52) which correspond with a higher potential for eutrophication downstream of the reservoir.

Expressed in load terms the trap of nutrients is equivalent with 7.6 KT P-PO_4/year (-35.7%) 64.4 KT N-NO_3/year (-22.4%) and 100 T/year (+4.2%) of chlorophyll a.

A an overall the Iron Gate Reservoir presents an uetrophication potential but with a lower magnitude due to continuous transport of water. No relevant D.O depletion was detected during summer period of time. The decrese of nutrient concentrations and loads downstream of the dam, on the other hand could be considered as a positive impact. However, in a mass balance, the transfer of organic matter with N,P content into sediment could create problems with Iron Gate sediments discharges from D.O. consumption point of view [5].

4.3. Heavy metals issues

In comparison with nutrients the problem of heavy metals is much more complicated due to distribution (transfer) process of them from the water column to the sediment, particularly at low water velocity as is the case of Iron Gate Reservoir. As a consequence the following characteristics were considered: (i) correlation between total and dissolved heavy metals fraction concentrations and loads at the inflow (Bazias) and outflow (Gruia) of the reservoir and (ii) sediment associated pollution. As was expected the ratios between total concentrations (out) / total concentration (in) are less than 1.0 but the same ratios reported to the dissolved fraction are increasing from 1.1 (Ni) to 1.9 (Cd) (table 3) which reflect a higher ecotoxicological potential downstream of the dam.

Tab. 3.

Correlation between heavy metals concentrations inflow (Bazias) and outflow (Gruia); Iron Gate Reservoir 2005

Heavy metals	Conc.	Equation	R^2
Ni	Tot	Y = 0.5156x + 0.2005	0.9728
	Diss.	Y = 1.0997x + 0.2294	0.9508
Hg	Tot	Y = 0.566x – 0.0022	0.8884
Cd	Diss.	Y = 0.4115x + 0.2337	0.9048
	Tot	Y= 1.8848x – 0.0641	0.9856
Pb	Diss.	Y= 0.276x + 1.4774	0.5026

	Tot	Y= 1.3979x + 0.0709	0.844
Cu	Diss.	Y= 0.6466x + 0.1545	0.7077
	Tot	Y= 1.2974x + 0.0398	0.749

The key problem however is "trap capacity" of the reservoir which is in the mean range of 62% for heavy metals about 940T of Cu, 840 T of Pb, 360T of cd and 760 T of Ni being retained in the Reservoir sediment during 2005. if, for the downstream area this might be considered as a positive impact for the Iron gate reservoir biota associated with the sediment it create a long term bioaccumulation process.

5. Dambovita river case study

In comparison with the usual cases where the waste water final effluent is diluted after discharge into the receiver in the case of Bucharest the satiation is reversed, the environmental flow being 10-15% (dilution less than 20%). Table 4 presents just one of the consequences in regard with priority hazardous heavy metals. As can be seen almost 83% of the concentrations (total) are maintained down stream of Bucharest due to very low dilution coefficient.

Tab. 4.

Concentration ratios Dambovita River downstream of Bucharest / final effluent (Glina) 2006

Heavy metals	**Range(%)**	**Mean value (%)**
Cd	65-80	72.5
Pb	80-95	87.5
Hg	80-90	85.0
Ni	80-94	87
	mean	83

6. Environmental protection water works needs and sustainable development

Romania is not a very rich land in water resources, in the natural regime of the rivers being possible to be assured about 1840 m^3 / inhabitant / year, in comparison with an average value of 4700 m^3 / inh/year at the level of Europe. As a consequence of a great variability of water resources in space and during the time it was necessary to modify the natural conditions by water works, particularly reservoirs with multiple purposes: water supply, hydropower, flood protection. As a result over 1650 reservoirs with a volume over 8 bill m^3 were realized in Romania the assurance of water needs being increasing to 2235 m^3 / inh / year (21.5%).

The hydropower water works are considered as the most important water user. In total there are 363 hydropower units out of which 125 with an installed power over 4.5 MW. The total installed power for the existing units is of 6075 MW and the mean annul hydropower is of about 20.750 MWh.

At the level of Romania the hydroelectrical power has a weight of about 5% in the primary energy production (mean value during 1999-2005). As an over all the national primary energy consumption is with about 34.2% higher than the associated production, being necessary to import natural gas and oil especially, but not the electrical power which, in the balance between export and import, is positive with about 150 thousand t.e.p/year.

Small hydroelectrical power plants (power of less than 10 MW) do not represents a major challenge for the Danube countries (1992- Cousteau report) might never the less contribute to diversification of production sources and the use of derived renewable energy sources. The impact of small hydroelectrical power plants (SHPPs) on the environment, though not negligible, can be controlled more easy. At the level of 1990 only 10% (0.4 TWh) of the economically operable potential for SHPPs (4TWh) were installed in Romania, and more than 100 potential sites have been listed.

In an IWRM, SHPPs development represent one of the solution in the energy sector despite the extreme ecologist point of view concerning the hydromorphological alteration.

7. Conclusions

The artificial lakes, particularly reservoirs for electricity production should be carefully analysed from the impact point of view, putting in the balance not only the consequences resulted from physical alteration but also the positive aspects especially for the extreme satiation (floods and drought).

Iron Gate Reservoir has to be judged, when WFD is applied in an upstream – downstream Danube River Basin wide approach. The eutrophication potential (2005) is not vey higher due to large proportion of the flow transfer (more than 90%). However if the trap of nutrients might be considered not very relevant for the sediment associated pollution with heavy metals the ecotoxicological potential at the level of the bottom biota is high.

If the environmental flow in the case of Iron Gate is not affected for other water works such as Dambovita River in Bucharest the problem is open even for the situation when a WWTP will be provided.

For a sustainable development, beside of other non conventional energy sources, the SHPPs potential should be (re) considered in an holistic approach based on IWRM concept. More that this the implementation of the WFD and other EU Directives impose a consistent enlargement of the WWTP network with a direct consequence in the electricity consumption, particularly in Romania where more than 50% of the population are not connected to the sewerage systems.

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* National Research and Development Institute for Environmental Protection – ICIM Bucharest Romania