EFFICIENCY IMPROVEMENT OF HYDRO-POWER LAKES CAPACITY BY COMBAT THE EXCESS DEVELOPED VEGETATION

RADULESCU V.
University Polytechnic of Bucharest, Splaiul Independentei no. 313, Bucharest
vradul7@yahoo.com

Abstract - The paper is structured in three different parts. In the first one are presented some hydrological climate physical and chemical conditions encountered into the analysed hydropower systems, responsible of the excess and unwanted developed vegetation. In the second part are presented the predominant types of vegetation and structures analysed during measuring campaign between 2005- 2006. Into the third part is detailed presented the proposed and implemented solution and mentioned the obtained results, during time, till 2010. It must be mentioned that the implemented solution to combat the vegetation is tested during more then three years into all analysed lakes. Finally are mentioned some conclusions.

Keywords: testing and modelling, environmental protection, efficiency improvement.

1. INTRODUCTION

Due to the fact that, most part of the hydropower lakes from our national energetic system, are realised more then 30 years ago (some of them 50 years ago!) permanent problems must to be solved during current exploitation. One of them is represented by the massive decreasing of the utile volume of lakes having as immediate effect a reduced efficiency of the entire hydropower systems. In present it is known that in Romania more then 20 such hydropower lakes have reduced capacity with more the 80% from the initial volume and other almost 40 with more then 60%. Some of them have reduced utile volume capacity due uncontrolled erosion and sedimentation; some other due to excess growth of unwanted vegetation. Into this paper it will be presented this second mentioned aspect. First will be analysed the main favourable conditions, responsible with such ecological disaster, especially into cases of cascade lakes. In second chapter it will be shortly presented some biological species of vegetation with rapid growth, fast adapted at our geographical conditions present into analysed hydropower lakes. Finally it is presented the adopted solution and the results of the implementation. It was implemented into the first lake (from four of the cascade lakes) just to be observed if there are any consequences after it into the other ones. During 2005 and 2007 systematic samples were be taken from lakes, during different time period of the years.

Year 2005 was (hydrologic speaking) a year with a huge amount of water. The area Siret, Bistrita, Buzau was confronted with 3 historic, repeated floods with human, animal and material loss and large areas covered by waters. Year 2007 for the same analysed area was the worst, the driest from the last 40 years (more then 20 days with red code). The rhythm of transport and water changes between cascade hydropower lakes is very important in evaluation of the chemical and physical structure of water amount. They are the main responsible into aquatic vegetation development. If the hydropower system is large (high volume) the rate of changes decreases.

1. THE PHYSICS AND CHEMISTRY OF THE ANALYSED HYDROPOWER LAKES

The tests realised during 2005 and 2006 let us to observe that the excess developed vegetation is due primarily into the existent sediments, as consequence of repeated registered floods from 2005. The physic and chemical parameters define huge nutrient value for the development of aquatic vegetation.

It must be made some remarks:

- The dissolved substances into water are the main argument of aquatic vegetation development
- Carbon after Hydrogen and Oxygen is the principal component, but presence of Phosphor assures a supplementary nutrient large then the Azoth and Carbon (due repeated floods)
- If into the hydrographical structure are discharged large amounts of Phosphor, in time induces decreasing of the Azoth; then Ciano-bacteria explode in number
- Azoth assure increasing of the ratio N/P and helps in development of azoth components

Oxygen lays the oxidation between water and sediments; the cycle became repetitive and the excess bacteria appear; then there is only one step to excess vegetation growth. Into Table 1 are mentioned some characteristics of analysed sediments and into the Table 2 the existent and the necessary substances to assure the development of vegetation (it may be seen that there are more then enough). Hydro-biologically speaking there was made researches referring plankton, flora and aquatic ecosystems. Practically there are two important vegetal categories: alga and aquatic plants.

The qualitative analysis of existent phytoplankton from the researched ecosystems consists into a number of

32 taxons, as it follows: Cyanophyta-3, Chrysophyta-2, Bacillariophyta-24, Pyrrophyta-1, Chlorophyta-1, Euglenophyta-1

Table 1. Average values of some parameters obtained during measurements into lakes water

Parameter	Lake I	Lake II	Lake III
Humidity (105^0C) %	55,46	53,38	55,66
pH (up H)	6,80	6,65	7,04
Organic Substances (%)	6,95	5,93	8,36
Mineral substances	93,05	94,07	91,64
NH^+_4 mg/100g	5,85	7,27	8,01
NH^+_4 mg/l	105,48	136,19	143,91
NO^-_3 mg/100g	0,33	0,41	0,19
NO^-_3 mg/l	5,95	7,68	3,41
PO^{3-}_4 mg/100g	0,068	0,072	0,086
PO^{3-}_4 mg/l	1,22	1,34	1,54
N- NH^+_4 + N - NO^-_3 mg/100g	4,61	5,74	6,27
P- PO^{3-}_4 (mg/100g)	0,022	0,023	0,028
$N_{dissolved}/P_{dissolved}$	209,54	249,56	223,93

Table 2. Resume of existent and necessary substances for vegetation development

Element	Symbol	Consume (vegetal) %	Water offer %	Consume / offer (approx.)
Oxygen	O	80,5	89	1
Hydrogen	H	9,7	11	1
Carbon	C	6,5	0,0012	5.000
Silica	Si	1,3	0,00065	2.000
Azoth	N	0,7	0,000023	30.000
Calcium	Ca	0,4	0,0015	<1.000
Potassium	K	0,3	0,00023	1.300
Phosphor	P	0,08	0,000001	80.000
Magnesium	Mg	0,07	0,0004	<1.000
Sulpha	S	0,06	0,0004	<1.000
Chlorine	Cl	0,06	0,0008	<1.000
Sodium	Na	0,04	0,0006	<1.000
Iron	Fe	0,02	0,00007	<1.000
Boron	B	0,001	0,00001	<1.000
Mangham	Mn	0,0007	0,0000015	<1.000
Zinc	Zn	0,0003	0,000001	<1.000
Cuprous	Cu	0,0001	0,000001	<1.000
Molybdenum	Mo	0,00005	0,0000003	<1.000
Cobalt	Co	0,000002	0,000000005	<1.000

During experimental data collection into the aquatic analysed systems we may observe that the algae numerical density is higher then the normal level into natural lakes (around 600 ex./ml); as example into lake II - 2333 ex./ml, into lake I- 1415 ex./ml and into lake III (due to the fresh water from other rivers) „only" 980 ex./ml. That means that into these three lakes the nutrients intake is too high, assuring developing of algae at this level, due to sediment transported from upstream.

The huge amount of algae represents a favourable aspect into developing al aquatic vegetation. In very short time some species became dominant and have major influence into local ecosystems: other species of flora are restricted, some species of fishes increase dramatically as number, etc.

Fig. 1 a, b. Prevalence of samples from lakes - 2006

Into the Fig.1-a, b are presented images during experimental vegetation acquisition. There is no need of any effort to extract vegetation; half meter from free surface is full of vegetation. During the entire year this real "vegetation carpet" is present. In Fig.2- a, b are presented some complex samples, during 2007.

Fig. 2 a, b. Samples of combined vegetation - 2007

Into Table 3 are mentioned the principal species of vegetation, just to observe how many species were developed into a very short time (under 3 years).

Table 3. Principal type of localised vegetation

	Lake where specie was present	I	II	III	IV (down stream)
	I. Plant total or partial into water				
1	*Cladophora glomerata*	+	-	-	+
2	*Spirogyra sp.*	+	-	-	+
3	*Fontinalis antipireticum*	+	-	-	+
4	*Equisetum fluviatile*	+	-	+	-
5	*Ranunculus acer*	+	+	+	+
6	*Ranunculus repens*	+	-	+	-
7	*Polygonum amphibium*	-	-	+	-
8	*Poligonum hydropiper*	+	-	-	-
9	*Elodea canadensis*	+	-	-	+
10	*Potamogeton amphibium*	-	-	+	-
11	*Potamogeton crispus*	+	-	+	-
12	*Potamogeton lucens*	+	-	+	-
13	*Potamogeton pectinatus*	+	-	+	-
14	*Myriophyllum spicatum*	+	-	+	-
15	*Ceratophyllum sp.*	-	-	+	-
16	*Juncus effusus*	+	+	+	+
17	*Typha angustifolia*	+	+	-	+
18	*Typha latifolia*	+	-	-	+
19	*Phragmites communis*	+	-	-	-
	II. Plant palustra				
20	*Salix fragilis*	+	-	-	+
21	*Dipsacus laciniatus*	+	-	+	-
22	*Mentha aquatica*	+	-	-	+
23	*Mentha longifolia*	+	-	+	-
24	*Bidens cernua*	+	-	+	-
25	*Rumex sanguineus*	+	-	+	-
26	*Eupatorium cannabinum*	+	-	+	-
27	*Inula britanica*	+	-	-	+
28	*Xantium riparium*	+	+	-	-
29	*Leucanthemum vulgare*	+	-	-	-
30	*Tussilago farfara*	+	-	+	+
31	*Potentilla anserina*	+	+	-	-
32	*Filipendula ulmaria*	+	-	-	+
33	*Sonchus arvensis*	+	+	+	-
34	*Epilobium roseum*	+	-	-	+

Fastest growing of these species was registered for: *Elodea canadensis, Potamogeton natans, Potamogeton lucens, Potamogeton crispus, Potamogeton pectinatus* şi *Myriophyllum spicatum.*

Due to all these mentioned facts a quick and efficient solution should to be adopted. It must be mentioned that from all these are realised alimentation with water for 6 major cities and other 102 small villages. Into scientific environmental communities confronted with similar problems.

2. SOLUTIONS TO COMBAT DEVELOPED VEGETATION FROM LAKES

During time were tested different methods, part of them was also in Romania.

- ***Chemical products***:

- algaecides - Use the effective chelated copper product on surface algae for a fast kill and assure a mix desired amount of substances with water when uniformly spray over the infested water surface. Best results were achieved when was applied on a calm sunny day. Heavy infestations were treated in sections with a 5-7 day "rest" between treatments to avoid oxygen depletion. Re-treatment during the growing season is required and is most effective when used when new growth first begins to appear.

- herbicides – Represent an effective systemic solution for control of most aquatic vascular plants. It is most effective when the water flow and discharge is minimal. Application is easy - simply pour into water body at several locations. Plants should be actively growing (water temperatures above 15^{o}C); but they don't kill algae and some other species. In many countries this solution is completely forbidden.

- ***Biological additives***–Generally use bio-augmentation to inhibit algae growth, reduce odours, and reduce sludge deposits while improving water quality. These highly concentrated cultures of naturally occurring microbes out-compete algae for necessary nutrients.

Any of these two solutions couldn't not be applied into the selected area due to the water supply for population (it was tested but the environmental and health committee interdict immediately).

- ***Mechanical control***- There are different solutions:

- **Harvesters** remove plants from the water, which alleviates water quality problems associated with the decay of cut plants left in place. These machines, Fig.3-a, cut vegetation, remove it from the water with a conveyor system and dispose of the plant matter onshore. They operate in depths of about 1m, and some are large enough to haul up to 13 tons of vegetation (densely packed water hyacinth can weigh 200 tons) Sometimes, separate shuttle barges transport the plant matter to shore while the harvester continues working. *Unfortunately*, plant harvesters also remove fish, amphibians, reptiles, birds, and other wildlife by including them in the harvested plant material

- **Rotovators** use rototiller-like blades to churn 0.5-0.8 m deep into the bottom, extracting the entire plant. They are primarily used for plants that have buoyant root crowns. The loose floating plants and roots are then collected and removed by an attachment to the machine, by harvester, or by hand. Rotovators, Fig.3-b, can clear large surfaces per day and are most often used in winter or spring when plants have died back. Control generally lasts for two growing seasons. *Rotovation is expensive and labour intensive*. The machines are difficult to manoeuvre, and bottom obstacles are problematic. Because rotovation severely disrupts the sediments, it can produce negative environmental impacts such as increased water turbidity, release of plant nutrients from the sediments, release of toxic residues bound in the sediments, and disruption of bottom dwelling animals, fish spawning and migration. There are many countries where rotovators are not used.

Fig. 3 a, b. Mechanical solutions

The mechanical solutions are expensive and not efficient. In time the rested vegetation is developed stronger then before and in large number (as grass cut in one year next year is getting stronger, denser). Generally natural species are developing in natural rhythm; invasive species growths faster.

- ***Grass carp*** – the solution was tested by importing some species from China; the control and use of such biological solution is not well tested at large scale. In Romania the solution was not efficient. Twice it was tried to populate the lakes with such fish species but they need of a temperature almost constant, around 18-24^{o}C. In to the analysed area more then 7 months/year temperature is around 10^{o}C.

- ***Bottom barriers***. This solution was proposed and tested into selected area. The first advantage is the lowest cost/ per treated area. The effects rest in time.

3. IMPLEMENTED SOLUTION

For the first time in our country were realised and tested during three years. Each panel are formed from other three subsidiary ones, covering a surface around 72 m^{2}.
Such bottom barrier or benthic barrier covers the sediment as a blanket, compressing the aquatic plants, blocking fully or at least partial the penetration of light. Materials like plastic, black Mylar may be used. In other country there are special material named Texel, a heavy plastic, sometimes used at special roads; nowadays it has a new destination. In Fig.4 is presented one bottom barrier during transport at the established location; the Romanian solution is more compact and easier to be transported.

Fig.4. Bottom barrier during transport

When the barrier is placed over vegetation, to be sure that it is not moved by the natural current of water or by different birds or animals it must be anchored at corners and at least into another six places. To decrease the final costs as anchors we put some local stones into some special realised recipients. Into Fig.5 it is presented the barrier. To be efficient it must be from black or any way dark material to assure the impossibility of penetration of light; the selected material was a solid plastic, used in construction.

Fig. 5. Bottom articulated barrier

Each barrier must rests into the same place 3-4 weeks. During this time a lot of cases (produced by vegetation covered by this barrier) must be evacuated. First time when we tried the barrier was completely destroyed by the produced gases. To avoid second time we execute many holes, Fig.6; time proved that the adopted solution is a correct one.

Fig.6 – The new solution of barrier

This method of combat the excess developed may to be used even from the beginning of the vegetation, earlier into March till end of November. In Fig.7 is presented an image during transport at to the selected area of first implementation. Into hydropower systems, the massive vegetation appears at small water, till 4-6 m, all around.

Fig.7. Image during implementation

The transport was carried by a boat and two divers.

Any other tested solution during time was not efficient; the chemical solution is not possible due to water supply, the biological solution was inefficient due small temperatures, the mechanical tested solution was a real disaster. Entire team hopes that the barrier will be a real solution. In Fig.8 is presented an image during installation of the system of anchoring of bottom barrier.

Fig. 8. Image during installation

For the future the team intends to experiment another material for the barrier, more resistant. During the transport of the barrier at the water surface must be verify that there is no branch to destroy the plastic. For the first time we install the barrier at the beginning of May 2007, and we let into the position for a month. We choose an area confronted with large amount of vegetation (see paragraph 2). During time when the barrier is on position is very important that it rest well anchored on bottom of the lake. It must be considered that, due to the fact that it has a hydropower destination, may be necessary to be made many manoeuvres during time cross the lake.

4. OBTAINED RESULTS

After one week a team verified the place where the barrier was placed. The firs photo was made, Fig.9. Already it may be observed that into the barrier area the vegetation change his colour. It doesn’t grows it doesn’t develop like into other places.

Fig.9. One week after installation

In June the barrier was transported into another location. Once anchors removed it floats at the surface, Fig.10. The divers move it carefully, not far away the first implementation, just to have an answer of question of influence area of the barrier. The entire team was curious of the efficiency of the solution.

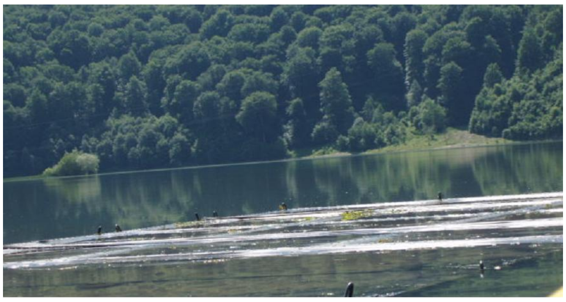

Fig.10. Image during movement to a new location

It may be observed that through his holes appears developed vegetation. When the divers tried to collect the rests they observed that's impossible. The vegetation is partially destroyed. In Fig.11 is presented an image with vegetation collected from vicinity of the bottom barrier.

Fig.11. Collected vegetation near vicinity of barrier

At it may be observed from the picture the vegetation has no roots. Partially it is destroyed. The colour has already changed his aspects; it is not full green as a month before, there are many places where it became brown due disintegration.

The divers moved the bottom barrier. Due the realised holes the emanated gases during dying vegetation and decomposition were evacuated. In to the first time the gases realised some spaces full of gases which finally destroyed the material of barrier. Now they are almost as new.

The divers returned to the place where it was first installed the barrier and try to collect some samples; t***here were no vegetations***, Fig.12, Fig.13.

Fig.12. Mud collected

Fig.13 a, b. Collected mud under the barrier

Into the place where the barrier was anchored there was no vegetation. After a month all types of plants, due absence of light and excessive temperature developed under the plastic material of the barrier. Even few meters all around the bottom barrier the vegetation is partially destroyed. The place where the barrier was installed was market to may be observed into the next year to see if the vegetation reappears.

From the Fig.14 it may be noticed as viewed from distance that place where the barrier was places the spot is darker, due to vegetation destroyed (macerated).

Fig.15. Dark spot of the macerated vegetation

In July the barrier was transported into a new location far away from the first tested area. In Fig. 16 is presented an image with developed vegetation with free surface, as before.

Fig.16. Developed vegetation into normal conditions

Finally is presented an image of the first place where the bottom barrier was installed, after two months.

Fig.17. Place partially cleaned by vegetation

5. CONCLUSION

The paper presents an implemented method as possible solution at a permanent problem, excess developed vegetation into the hydropower lakes. It was considered for analyse a cascade lakes confronted with huge amount of vegetation. During year 2006 were extracted from the second lake more then twenty times more vegetation then in 1996. If in year 2001 were extracted around 100 kg/grill into 2006 were extracted around 176 kg/grill.

During time there were tested another solutions. None of them have reasonable results. Chemical solutions are not allowed. Biological solutions were a failure; the fishes died due to natural different conditions. Mechanical solutions are very expensive and unacceptable for our local conditions. It should be tried something else. The proposed solution was a success.

The area where the bottom barriers were implemented was observed and during 2008-2010. Generally we may appreciate that the "treated area" now is partially released by vegetation.

Finally we may mention some clear advantages of this solution:

- The cost of implementation is advantageous; all the materials are from the free market and the price of the solution is lower then the biological and mechanical one.
- The bottom barrier may me placed starting March till November. During this time at each 3-4 weeks they could be moved; then the covered area increase.
- In places where the barrier were placed the vegetation don't grows as into free places. It is reduced as quantity and it has no resistance; it looks like "diseased vegetation".

Remarks:

- Places where the bottom barrier is installed should me marked. The personal from current exploitation of the hydropower system should not travel across with boats. The barriers could be destroyed.
- In time will be studied the influence of the barrier on biological ecosystems (fishes, frogs, birds, etc).

The solution was extended and into another cascade of hydropower lakes, starting 2010. Till now the obtained results confirmed the opportunity of the proposed solution.

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