

## BRADISOR LAKE RESTORATION AFFECT TO EUTROPHICATION PROCESS

Gabriela Elena DUMITRAN<sup>1</sup>

*Lacul Brădișor este principala sursă de apă proaspătă pentru Râmnicu Vâlcea. Evoluția acestuia în ultimi 10 ani a fost de la ultraoligotrof în 1996 la hipereutrof în 2004. Articolul prezintă unele soluții pentru reabilitarea ecologică a lacului Brădișor considerând un ecosistem dinamic și stipularea unor domeniilor variabile spațiale și temporale pentru proceselor naturale ce apar și acționează asupra factorilor perturbatori pentru a modifica succesiunea ecologică.*

*Restaurarea ecologică a ecosistemului acvatic este un proces foarte complex și ușurează revenirea ecosistemului la o stare autonomă, prin acțiuni asupra factorilor fizici, chimici și biologici.*

*Bradisor Lake is the primary source for fresh water for Râmnicu Vâlcea, and its' evolution for the past 10 years is from ultraoligotrof in 1996 to hipereutrof in 2004. The article's aim is to present some solution for ecological rehabilitation of Bradisor Lake, by considering the ecosystem dynamic and the stipulation of the spatial and temporal variation domains for the natural processes to appear and act onto perturbation factors to modify the ecological succession.*

*The ecological restoration of aquatic ecosystem is a very complex process and eases the ecosystem restoration to an autonomous state, by actions onto physical, chemical and biological factors.*

**Keywords:** lake, ecosystem, eutrophication, restoration.

### 1. Introduction

Pollution has become a social and economical problem of our days, which in some parts of the world and especially in heavy industrialized countries has led to the endorsement of drastic measures for the limitation of hazardous wastes being disposed of in aquatic ecosystems. In order to protect the environment it is necessary to urge the usage of technical and scientifically developments as well as embracing firm juridical, economical and constructive measures. Eutrophication on worldwide scale, as an effect of the anthropic impact, is one of the most serious problems that affect the quality of the water.

Eutrophication represents a specific form of surface water pollution, due to an increase - over certain limits - in chemical nutrients. The main effects of eutrophication are an increase in turbidity (cloudiness) of water, development of

---

<sup>1</sup> Lecturer, Dept. of Hydraulic, Hydraulic Machines And Environmental Engineering, University "Politehnica" of Bucharest, ROMANIA

anoxic conditions (low oxygen levels), modify the carbon dioxide concentration and the pH value, modify the organism's quantity and quality and decrease in the amenity value of the water (e.g. it may become unusable). Now day's eutrophication is one of the most serious problems which affect water's quality. Surveys showed that in developed countries 65% of lakes are eutrophic, while, on a global scale, the eutrophic lake percent is of 45% (54% of lakes in Asia are eutrophic; in Europe, 53%; in North America, 48%; in South America, 41%; and in Africa, 28%), [2].

The ecological rehabilitation of aquatic ecosystems is a very complex process and eases the ecosystem restoration to an autonomous state, by actions onto physical, chemical and biological factors. Ecological rehabilitation must be build on solid theoretical knowledge's, implying the return of the ecosystem to the state prior the perturbation, or very close to this state, but considering the changes of the hydro graphic watershed. After rehabilitation, the state of the system must be self-supporting and the natural dynamic processes to be operable again.

## 2. Eutrophication phenomena

All artificial lakes from the temperate climate are affected by direct or inverse thermal stratification (fig.1). The temperature/density vertical profile established in lakes is the result of thermal energy and two mixing processes (convective cooling and turbulent mixing) overlap.

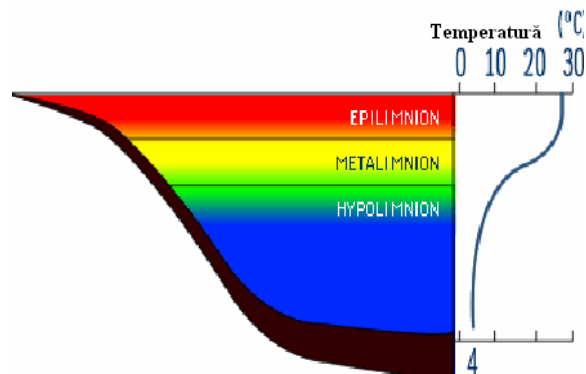


Fig. 1. Lake direct thermal stratification

A typical temperature/density profile for a temperate lake is composed from two layers of small temperature/density (epilimnion, hipolimnion) divided by a layer of high temperature/density gradient (metalimnion). Stratification stability and hydrodynamic regime are influenced by the presence of temperature/density gradient, [1].

In the hipolimnion layer, the lack of oxygen causes anaerobic reactions and the apparition of products that alter water quality (sulphuretted hydrogen, ammonia). This is the reason why it is very important to assure the temperature/density homogenization in order to prevent eutrophication, especially in the case of lake's used as drinking water sources.

Over the year, the changing climate imposes a certain water dynamic at the lacustrian ecosystem level. Thus, lake's water suffers two stratification cycles (during summer and winter) and two mixing processes (during spring and autumn). The processes involved affects water quality and represents interactions between physical, chemical and biological processes.

The water resources from a lake must be adequate to be used in various ways. Thus, in order to administer the resources it is necessary to preserve the ecosystems' balance, which includes knowledge of how the ecosystems work through a multi-subject research, associated with experiments and modulation. It is known that the physical, chemical and biological processes that take place inside a lake are very complex. The difficulties in understanding come, mainly, from the fact that, within an artificial lake, there is a complex interaction between the processes.

### 3. Restoration of lake and reservoirs

Eutrophic lake restoration is a very complex process, which consist in bringing the system to a state according with its use. The ecological rehabilitation of aquatic ecosystems eases the ecosystem restoration to an autonomous state, by actions onto physical, chemical and biological factors. Ecological restoration must be build on solid theoretical knowledge's, implying the return of the ecosystem to the state prior the perturbation, or very close to this state, but considering the changes of the hydro graphic watershed. The restoration techniques involve action of physical, chemical and biological nature, and just a few of them are long term efficient, [4]. Among the measure with direct effect onto the affected lacustrian ecosystem are destratification and hipolimnion aeration. After restoration, the state of the system must be self-supporting and the natural dynamic processes to be operable again.

Lake restoration techniques are divided into four categories, based on their considered primary objective:

- to control problems caused by algae;
- to control excessive macrophyte biomass;
- to alleviate oxygen problems;
- remove sediment.

**Algal problems.** Because algal biomass is dependent on the concentration of limiting nutrient in the lake's photic zone, the techniques for

control problems are multiples:

- nutrient diversion/advanced waste treatment consist to a reduction in external loading in the first step. While it is possible to manipulate algal biomass through enhanced grazing or by light limitation;
- internal release of phosphorus may be significant source that could delay recovery/improvement of lake quality. Sediment phosphorus release can be controlled by adding aluminium salts to the water column resulting in an aluminium hydroxide floc that settles to the sediment surface forming a barrier to further release, even if anoxic persist. Addition of iron or calcium has also been effective in some circumstances;
- dilution/flushing. Dilution involves the addition of low-nutrient water to reduce lake nutrient concentration and can be effective where external or internal sources are not controlled. Flushing simply removes algal biomass, although that may require large volumes of water if nutrient concentration is high and not limiting;
- land use modifications can be used to control nutrient loss from the watershed and thus improve lake quality, but they are usually used to protect lake quality from further degradation in areas undergoing development;
- hypolimnetic withdrawal. Nutrient enriched hypolimnetic waters may be preferentially removed through siphoning, pumping, or selective discharge instead of low-nutrient surface water. This has been shown to be effective at accelerating phosphorus export, reducing surface phosphorus concentrations, and improving hypolimnetic oxygen content;
- artificial circulation with is used to prevent or eliminate thermal stratification through the mixing action of a rising column of air bubbles. It can be used to limit algal growth in situations where nutrients are uncontrollable and can neutralize the factors favouring dominance by blue-green algae;
- grazing of algae by large zooplankton can be enhanced by eliminating planktivorous fish through poisoning, physical removal, or increased piscivory;
- copper sulphate treatment.

Although *macrophyte problems* often are associated with eutrophication and increased inputs of sediment, control of their growth and biomass cannot be expected to result from reduction of in-lake nutrient concentrations. The methods employed to deal with excessive macrophyte biomass are:

- harvesting; removing macrophyte biomass from lakes is often an

effective treatment to control a nuisance macrophyte problem. This method can have negative effects, such as dispersal of plant fragments to uninfected areas, removal of small fish and encouraging sediment resuspension and sediment phosphorus release;

- biological control with consist by dispersal of phytophagous insect and fish has become more prominent as inexpensive, effective controls on macrophyte biomass;
- lake-level drawdown consist in exposure of rooted plants to freezing or hot conditions eliminates some species, does not affect others, and stimulates a third species group;
- sediment covers consist in screening materials with purpose to stop rooted plant growth;
- sediment removal control of both algae and macrophyte biomass. It is a procedure recommended for deepening shallow lakes for macrophyte control, curtailing internal nutrient loading by eliminating the enriched sediment layer or eliminating sediments contaminated with toxic substances.
- hypolimnetic aeration it is technique with increasing dissolved oxygen in the hipolimnion without destratifying the lake or reservoir.

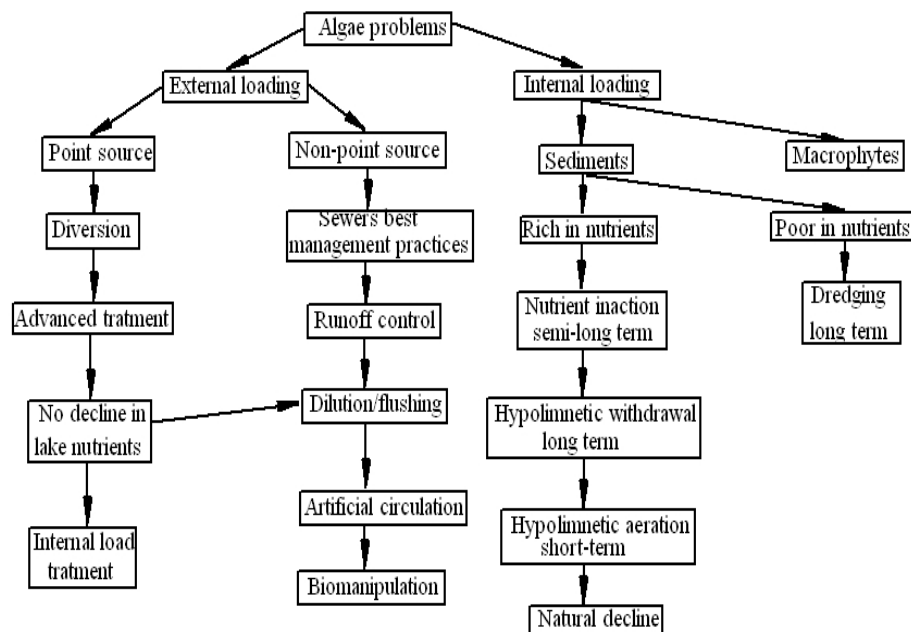


Fig. 2. Decision tree for choice of best procedures for control of algae problems, [3].

The appropriate technique to apply to a specific lake requires a decision based largely on judgement. To make the proper decision, the lake manager will

probably go through a decision process in which one or more of the 16 techniques described. Such a decision process may take the form of figure 2, for algal problems.

#### 4. The Bradisor lake presentation

The Bradisor hydropower plant is the last step of Lotru hydro energetic arrangements. The reservoir Bradisor retains the diffluent flows from CHE Malaia and intake water Păscoaia and its make a flow seasonal-year regulation through basin difference. These lakes are characterized by:

Table 1

Lake characteristics					
Normal Level Retention	Total volume	Available volume	Lake surface at NRN	Length	Breadth
452 mdM	39 10 <sup>6</sup> m <sup>3</sup>	35 10 <sup>6</sup> m <sup>3</sup>	229 ha	5000 m	700 m

Bradisor Lake is the primary source for fresh water for Râmnicu Vâlcea town and it are the evacuation from hypolimnic level. Its' evolution for the last years is from oligotrof in 1994 to hipereutrof in 2004, with evolution come in figure 3.

The thermal stratification of Bradisor Lake and the solar radiation are the most important factors which make the vertical dynamic distribution of phytoplankton. The plane distribution of phytoplankton is in decrease from tail end of lake to dam, with major values around of fish farm.

The major sources of nutrients and organic matter to Bradisor Lake were believed to be "non-point" sources as fishery activity.

Because of the Malaia Lake was empty in October 1997, the Bradisor Lake was complete unbalanced. Therefore, the ecosystem was suffering chemical and biological modifications with biological effects.

Table 2

Lake trophic evolution			
Year	Total Biomass (mg/l)	Throphic state	Characteristics
1994	2.52	oligotrof	
1995	3.67	oligotrof	
1996	0.43	mezotrof	
1997	0.59	ultraoligotrof	
1998	0.57	ultraoligotrof	
1999	1.865	oligo-mezotrof	
2000	1.37	mezotrof	
2001	4.33	mezotrof	Fragillaria crotonensis in overspill
2002	9.27	eutrof	Ceratium hirundinella in overspill
2003	3.31	mezotrof	Ceratium hirundinella in overspill
2004	10.27	hipereutrof	Algal bloom (Anabaena solitaria)

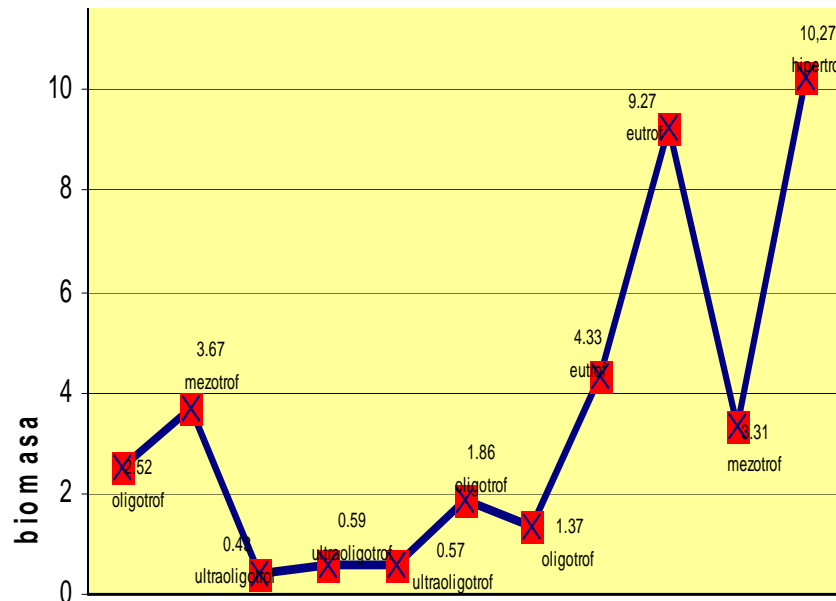


Fig. 3. The Brădişor Lake throphical evolution

Concerning the physic and bio-chemical indicators in Bradisor Lake it is demonstrate that the eutrophication process is sustained from fishery activity. Therefore, the farm trout witch is placed in the lake is perturbing factors for the aquatic system with sever consequences for the water quality.

### 5. The Bradisor lake restoration

The great nutrient loading in the Bradisor Lake generate a want with it is manifest in phytoplankton bloom. This bloom generates a diminution of light intensity. From this reason the photosintetisant organism ascend to the surface. All those factors product the eutrophication phenomena.

The restoration of Bradisor Lake will be based on phosphorus inactivation or artificial circulation.

Successful protection of Bradisor Lake from non-point external loading may appear to be difficult, especially when drainage area greatly exceeds lake area and there are many sources of potential soil and nutrient loss. Nevertheless, there are several methods with great potential to significantly lower non-point loading of silt and nutrients. These methods all require work in the drainage area itself, meaning that lake manager often have to become land managers and terrestrial ecologists as well.

Phosphorus retention and storage are among the most important functions of constructed wetlands. Sediment and peat accumulation are the major

mechanisms of long-term phosphorus storage. Uptake by plants and their epiphytes, and sorption to soil surface are primary processes that change wetland water phosphorus concentrations over the short term, but plants and epiphyton release 35 – 75 % of phosphorus back to the water column, especially at the season's end, [5]. Reactions of phosphorus with salts of iron, aluminum and calcium are major processes in phosphorus storage, and are controlled by initial soil phosphorus concentration, pH, and oxidation/ reduction potential. Figure 4 summarized phosphorus retention processes in wetlands.

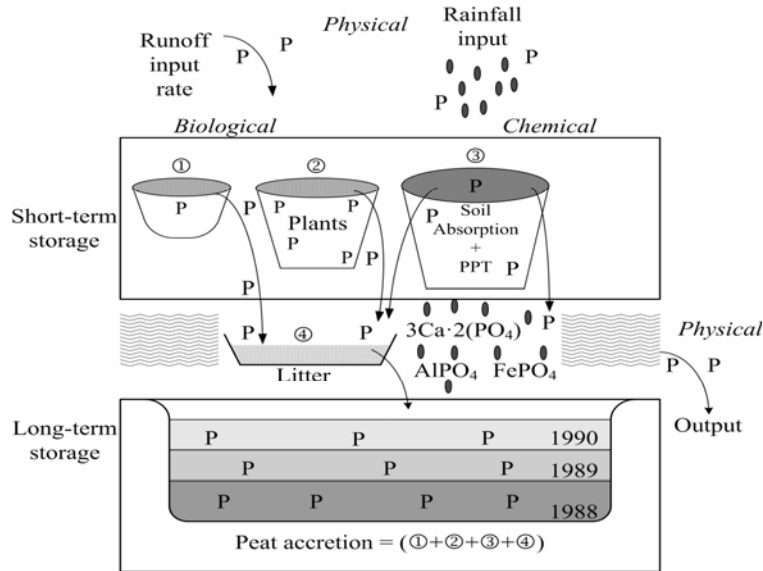


Fig. 4. A conceptual model of phosphorus retention in wetlands [8].

If a constructed wetland is to provide sustainable phosphorus storage, phosphorus input cannot exceed the rate of permanent peat or soil formation. Processes producing soil and peat of the wetland can be impaired by excessive loading. For this kind of technique, many factors must be considered, including seasonality, hydraulic and meteorological constraints, and specific wetland characteristic.

Pre-dam is commonly used in Germany, to protect downstream reservoirs from nutrients and silt, [6]. Pre-dam may also protect water supplies from accidental or purposeful spills of toxic or radioactive materials. Most pre-dam have a water residence time of several days, possibly allowing time to close raw water intake and/or treat the contaminant water.

Pre-dam normally has a surface overflow plus a deep gate to allow water removal followed by sediment removal. They function primarily through sedimentation of particulates, and nutrient removal occurs by maximizing diatom



growth and sedimentation while minimizing blooms of buoyant cyanobacteria and algae grazing from consummators, to prevent remineralization.

Nuisance algae blooms can be reduced or eliminated if phosphorus concentrations are lowered to growth-limiting levels by diversion of external loading, by dilution, or a combination of these methods.

Phosphorus inactivation is an in-lake technique, designed to lower the lake's phosphorus content by removal of phosphorus from the water column and by retarding of mobile release phosphorus from the lake sediments. Usually an aluminum salt, either aluminum sulfate, sodium aluminate, or floc to which certain phosphorus fractions are bound.

Summer lake trophic state is improved when the control of internal phosphorus release significantly lower phosphorus concentration in the photic zone, which is the epilimnion and sometimes the metalimnion of eutrophic dimictic lakes (with two complete circulation per year).

A restoration technique to oxidize the top 15 -20 cm of anaerobic lake sediment reduces the internal phosphorus loading in lake that have anaerobic sediment and high interstitial phosphorus concentrations, and in which iron redox reactions control phosphorus interchange between sediment and the overlying water. By oxidizing the organic matter through increased denitrification, greater binding of interstitial phosphorus with ferric hydroxide complexes should occur, resulting in lower release rates for phosphorus.

Artificial circulation, also referred to as destratification and hypolimnetic aeration/oxygenation are two general techniques for aerating lake. Circulation has been achieved by pumps, jets, and diffused air. Complete lake circulation is usually the objective, and in the majority of cases examined either stratification was prevented or destratification occurred. Unlike hypolimnetic aeration/oxygenation, the temperature of the whole lake is raised with complete circulation; the greatest increase in temperature occurs at depths that were previously part of the cooler hypolimnion. The principal improvements in the water quality caused of substances by complete circulation are oxygenation and chemical oxidation in the entire water column.

## 6. Conclusions

The both analyzed restoration techniques for Bradisor Lake are efficient for eutrophication problems that appear in lake. The phosphorus inactivation or artificial circulation will be able to cause a decrease of primary production and an improvement of water quality in lake.

## REFERENCES

- [1] *G. Dumitran*, Elemente de ecologie pentru ingineri, Editura Politehnica Press, 2008;
- [2] *L. Jugnia, D. Debroas, J-C. Romagoux J. Dévaux* Initial results of remediation activities to restore hypereutrophic Villereest Reservoir (Roanne, France) in *Lakes&Reservoirs:Research and Management*, **Vol. 9**;
- [3] *D. Cooke, E. Welch, S. Peterson, S. Nichols*, Restoration and management of lakes and reservoirs, Taylor&Francis Group, 2005;
- [4] *M. Scheffer*, Ecology of shallow lake, Chapman&Hall, 1998;
- [5] *M. Coveney, E. Stites, L. Lowe, R. Battoe*, Nutrient removal from eutrophic lake water by wetland filtration, *Ecology Engineering*, **vol. 19**, 2002;
- [6] *L. Paqul*, Nutrient elimination in pre-dams: Results of long term studies, *Hydrobiologia*, **vol. 504**, 2003;
- [7] *E. Welch*, Ecological Effects of Wastewater applied limnology and pollutant effects, Chapman&Hall, 1992;
- [8] *C.J. Richardson, C.B. Craft*, Effective phosphorus retention in wetlands:Fact or fiction?, Lewis Publisher, 1993.