# NEW TECHNOLOGICAL MODEL USING PV TO COLLECT AND PARTIALLY DRY THE ACTIVE SLUDGE FROM NATURALS OR HYDROPOWER LAKES

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**Abstract - The present paper is structured in six parts. In the first part are mentioned the topic importance and the new problems appeared into last decades, related to the environmental problems in natural or hydropower lakes. This new solution using renewable resources based on PV-photovoltaic panels intends to resolve these aspects. As area for testing were selected two natural reservations lakes. Based on some experimental measurements made during three months in 2015, was determined the quality of water, main parameters, presented in part two. In the third part are briefly presented the actual environmental conditions and in part four the effects on the active sludge deposits appeared due excess developed vegetation. In part five is presented the prototype model used to solve the local problem, to collect, compact and partially dry the active sludge. The extracted sludge can be in short time integrally consumed for agricultural purpose, as ecologic and nutritive fertiliser as to restore the agriculture lands. The sludge, knew in the past for its therapeutic utilisation, more then one hundred ago, nowadays due ecological and biological changes lost his efficiency. The reconstruction of the local ecologic balance and for the sludge to recover its therapeutic properties using renewable resources without disturb the environment are the main objectives of this research. Finally some conclusions and references are presented**

**Keywords:** environmental protection, renewable resources, modelling, prototype, automation

## 1. INTRODUCTION

At present, due to eutrophication many lakes have the utile capacity diminished [3], followed by a massive deposition of the active sludge and an increasing of the aquatic vegetation. In short time appeared massive development of invertebrates, interference scallops and predators fishes, and in the same time a decline of the specific fishes for that area.

To solve the problem was realized an experimental model, an autonomous pilot station placed on a mobile pontoon, powered in co-generation with PV panels, to collect, compact and partially dry the active sludge. The sludge, due its structure full of nutrients and nitrates, in concentrations perfectly ecologic is used as a biologic fertilizer to restore the soils affected by demineralization. By repeated applications the lands are restored and play-back for agriculture; the yields were higher on the tested land. The tested solution is ecologically and has as main objective to rebuild and reconstruct the biological equilibrium of the area in which it is applied, two Natural Reservations: Lake Mangalia and Lake Techirghiol.

The tested methods till now do not represent efficient solutions. Small islands appeared, modifying the bio-chemical structure of water and of the sediments, affecting the endemic biologic species, [5]. Excessive vegetation is deposited on shore; the decay affects the environment and the natural life from reservations.

The proposed solution is innovative, autonomous, ecologic mobile and utilise renewable resources. The photo-voltaic panels ensure the pontoon movement and the partially supply of the collecting, partial drying and compacting of the sludge. The advantage of this solution consists in fact that extracted sludge can be immediately and integrally consumed for agricultural purpose as to restore the agriculture lands. Due incorporated automation the installation can adapt the functioning parameters in accordance with meteorological conditions.

Due some local works as to restore the shore, clean water enters into lake and changed the water salinity. In short time was observed perturbation into environment conditions [2]; species of aquatic vegetation and endemic invertebrates, specific to clear water appeared and developed. That was the reason why [1], was monitored the water parameters during three months and were realized measurements in different points of the lake.

The reconstruction of the local ecological balance without using conventional fuel as to not disturb the ecologic equilibrium of the reservation represents the main objective of this research. During migration in the mentioned lakes areas are present more than 20.000 birds of different species, many of them being law protected.

The solution has a double benefit: to restore the ecologic equilibrium and to assure a proper and efficient consumption of the extracted sludge, as organic fertilizer on affected soils. By partially drying, the time till economic utilization is shortened and also restricted the development of insects and the putrefaction of parasitic midges. There are used renewable resources as energy resource to collect, compact and partially dry the sludge.

This solution is according to Romania reply for EU Council Directives, UE, EUCO 75/13 CO EUR 7 signed

in Brussels at 22/05/2013, referring at promotion of new solutions based on utilization of renewable technology.

## 2. THE LOCAL QUALITY OF WATER

During 2014-2016 were made measurements of water quality in both lakes. In summer 2015 for three months was created a data base structured on systematic measurements. In Fig.1 is presented the boat for the data acquisition, where ADCP is Acoustic Doppler Current Profilers. In Fig.2 are mentioned some sedimentation tests made as to monitor the viscosity of water samples, at 20 cm above the sedimentation bed.

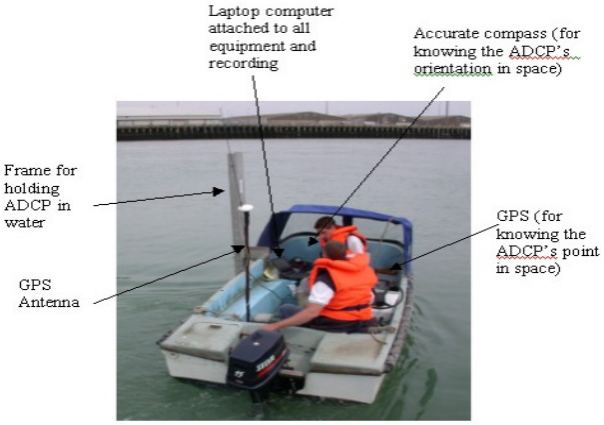


**Fig. 1 - Boat for measurements**

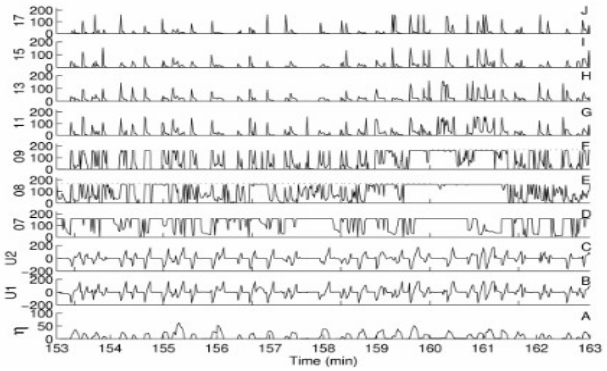


**Fig. 2 - Variation of viscosity**

The estimation of water from the aquatic domain parameters includes many aspects, such as: water level or water depth, nutrients, light availability, sediments, and pressure [4]. During our measurements were registered nine aquatic environmental and water quality variables: WL-Water level, SDD-Sediments deep deposition, TSM-Total suspended matter, TN-Total nitrogen, DTN-Dissolved total nitrogen, ammonia $NH_4^+$-N, TP-Total phosphorus, DTP -Dissolved total phosphorus and chlorophyll a *Chl-a*. Chlorophyll was extracted with ethanol (90%) at 80°C and analyzed by spectrophotometric apparatus. In Table 1 are mentioned partially some obtained values. Samples were filtered by a pre-combustion at 450°C for 3h and after that filtered at nominal sizes greater than 0.7$\mu$m. After that the samples were dried at 110°C for 3 h and were measured as to obtain the sediment weight and to calculate the TSM (total suspended mass) concentration.

It was used the FAI-First article inspection method to obtain the sediment distribution for each image made during the monitoring interval [7]. The FAI method is robust and responds to all the conditions into the study area, including the conditions of water affected by dissolved organic matter, thick oxygen and frequent sunlight reduced in water, during the summer. The area with aquatic vegetation can be distinguished from open water based on a critical FAI threshold.

**Table 1. Water composition**

| | WL m | SDD m | TSM mg/L | TN mg/L | DTN mg/L | NH4+-N mg/L |
|---|---|---|---|---|---|---|
| Min | 4,02 | 0,43 | 12,74 | 0,52 | 0,34 | 0,055 |
| Max | 4,21 | 1,17 | 49,82 | 2,03 | 1,64 | 0,510 |
| Mean | 3,24 | 0,83 | 29,11 | 1,14 | 0,92 | 0,242 |
| SD | 0,11 | 0,29 | 14,10 | 0,42 | 0,39 | 0,137 |

| TP mg/L | DTP mg/L | Chla µg/L | VPF |
|---|---|---|---|
| 4,02 | 0,034 | 0,014 | 2,580 |
| 4,21 | 0,072 | 0,032 | 16,300 |
| 3,24 | 0,054 | 0,023 | 7,020 |
| 0,11 | 0,012 | 0,010 | 3,780 |

The FAI threshold of aquatic vegetation was set to −0.03, which has been validated by previous measurements made in 2004. When the FAI of pixel j exceeded the FAI threshold of −0.03, the value of this pixel was set to 1 in the FAI layer; otherwise, the value of the pixel was set to 0. The VPF was evaluated for n points:

$$VPF(i) = \frac{\sum_{i=1}^{n} FAI(i,j)}{n} \quad (1)$$

where VPF represents the frequency of the pixel i in a set of n points, from the selected measurements.

## 3. ENVIRONMENTAL CONDITIONS INTO LAKES MANGALIA AND TECHIRGHIOL

In Fig.3 and Fig.4 are presented images with these two lakes; both of them are situated really close to the Black Sea, and nowadays Natural Reservations.


**Fig. 3 - Lake Techirghiol- Natural Reservation, very close to the Black Sea**

**Techirghiol Lake**

Techirghiol Lake is the largest salt lake in Romania, having a large body of water (1226.97 hectares) located in the immediate vicinity of the coastline, approximately 15 km south of Constanta. Its name means Lake of mullets (Mullus barbatus). Sludge and lake waters are used for their health-resort ability since the 19th century and it is produced as a result of bacterial decomposition of the aquatic organisms after finished their natural cycle, by the especially shellfish Artemia salina and marine algae that live in his water.

Techirghiol salinity measured in 1996 was 81.485 g/l, as in the 2000s reaches at a level below 60 g/l, which prove a cumulative effect of natural fluctuations but also some environmental appeared problems, [9]. High salinity, due to almost permanent wind which mixed lake waters leads to a very rarely freezing water, especially from the waters of the middle of the lake. This characteristic of water that remains unfrozen even if the temperature gets to -2 or -3 degrees during winter makes the place attractive to numerous wintering waders.

Legal protection of these two lakes is provided by Decision 1266/2000. Techirghiol and Mangalia were declared RAMSAR sites in 2006, with the number 1610, 1612. Techirghiol is included in Nature 2000 on the basis of the EU Birds Directive, having RoSPA0061 code.

More than 150 species of birds, various species of fishes are present at different times of the year. The water surface has an altitude between 0 and 80m; the area is in the vicinity of the Black Sea. In the migration periods the waters of the site are used for waders more than 20.000 birds. For all of them the main food is represented by marine species of fish, small frogs or snakes and specific vegetation for salt waters.

Currently, the Techirghiol Lake waters are divided into three separate entities due to the dams constructed in 1983 and 1989. There is an area with salt water (52-55 grams of salt per litter) located near the east sea, brackish area (6 -8 g/l) intermediate and freshwater area (1 to 2.3 g/l), located at the "end of the lake". The western area has in present areas fills of marsh vegetation characteristic for freshwater, Fig.5.

**Mangalia Lake**

The old **s**wamp between Mangalia and Saturn, appeared due sand deposition more than 100 years ago, and separates a part of the water from Black Sea, forming the Mangalia Lake. It has a surface of 99 ha. During the winter the lake is a shelter for many species of birds which prefer deltaic environment: coots, pelicans, ducks, geese, cormorants, swans. Nowadays the lake is confronted with local eutrophication. In Fig.4 may be seen the effects of the eutrophication [8] development into Mangalia Lake.


**Fig.4 - Lake Mangalia - Natural Reservation**

Both lakes are confronted with the same problems:

- decreasing of the water salinity
- excessive development of aquatic vegetation specific to fresh water, the more as none of these two lakes freeze in winter
- reducing of the space where birds can make their nests
- decreasing in number of the marine fish species
- development of the species specific to freshwater that feed on vegetation newly emerged

In Fig.5 are presented excess developed vegetation and in Fig.6 some invasive species collected from lakes during summer 2015.

**Fig.5 - Invasive vegetation collected from lakes**

**Fig.6 - Invasive species collected from lakes**

In Fig.7 are presented images with the life conditions for birds from local areas; the images speak for themselves about the life conditions.

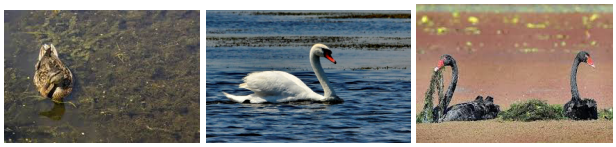

**Fig.7 - Life conditions for birds**

The appeared lagoon effect, allows the development of shells, and predatory fish. These species have proliferated, despite the endemic fish species. As immediate effect a massive destruction of nests from some protected by law birds species from this area appeared. Bird species, considered rare, are nowadays endangered. Amber rate, Califar, Black-headed gull, Dobrogean hawk decreased dramatically in number over the last 10 years.

## 4. ENVIRONMENTAL EFFECTS OF EXCESS DEVELOPED VEGETATION

Being natural reservations there can not be used chemical or biological methods as to control the sediments or manipulation of the water levels as to combat the excess vegetation [10].

Dense growths (over 25% of the surface area) of algae and other water plants can seriously interfere with normal aquatic life and definitely affect the life of birds, producing discrepancies in normal environmental:

- during the night time the oxygen depletion has supplementary biological effects; the green plants produce oxygen in sunlight, but they consume oxygen during the night and reduce once more the percent of dissolved oxygen from water

- decomposing water can deplete the oxygen supply, resulting in fish killed by suffocation

- the growth of dense plant can provide too much cover of water and reduce the amount of light that can penetrate, inhibiting photosynthesis (and oxygen production) of plants in deeper waters. Anything that stirs or brings these deoxygenated waters to the surface (such as a strong wind) can lower oxygen levels throughout the water column and cause the dead of fishes. Even if it doesn't kill the fish, prolonged exposure to low oxygen concentrations can weaken the fish, making them susceptible to diseases and toxicants

- excess plant growth can provide too much shelter for small fish and reduce the predation. This leads to an overpopulation of the prey fishes

- decomposing algae and plants also contribute to oxygen depletion. When plants die, bacteria and fungi break down the decaying plant material. This process uses up the oxygen from the water. Plant death and decomposition can occur in midsummer, the period when birds need more food to feed their babies-birds.

## 5. NEW SOLUTION TO UNPLUG THE SLUDGE DEPOSITED IN LAKES

The proposed solution is innovative, autonomous, perfectly ecological, partially energetic independent, placed on a mobile pontoon, commanded from distance, powered in co-generation by photovoltaic panels. They ensure the pontoon movement and partially the supply of the collected, compacted and partially dried of the unplug sludge. The drying of the sludge is realized in a fibber glass tank, located under the PV. It represents a natural fertilizer used for low mineralized lands, to restore the bio-chemical potential.

The solution has a double benefit: to restore the ecologic equilibrium from the areas where it is implemented and on the other hand an efficient consumption of the extracted sludge, as organic fertilizer on affected soils. By additional drying, the time till economic utilization is shortened; also it is restricted the development of insects and the putrefaction of parasitic midges [9]. The proposed experimental solution is efficient, by using renewable resources as to participate at restoration of agricultural lands. It can be moved in different areas, the rest of reservation being completely unaffected. There are used renewable resources of energy to collect the sediments sludge into natural or upgraded lakes, which affects the entire ecologic equilibrium, a complex and actual problem, especially into the protected areas [1], [2].

In Fig.8 is schematically presented the installation structure, based on three functional blocks: the collecting system coupled to PV noted Block 1, the system for compacting, noted Block 2 and the system for partial drying, coupled also at PV noted Block 3. Separately are designed and executed the command system of movement from the lake shore, the automation system to stop the pontoon when the fibber glass is fulfil with sludge, and the automation system to coordinate one cycle and finally the alimentation system from the PV panels. Between all blocks is realized a system of inter-connection. Further is briefly presented the functioning principle and the main components:

1- The command system
2- The collecting system
3- Fibber glass tank
4- Warm water closed circuit
5- Automation system
6- System of drying the sludge
7- Installation of compacting the sludge
8- Could water circuit
9- Evacuation of sludge for agricultural purpose
10- PV panels

During the advance, the pump aspire sludge and sediments. The sludge is conducted directly into a compacting system (7). At a time interval, the compacting system is started. Further is deposited into a fibber glass tank (3) as to be partially dried. At the moment of full fill, the automation system interrupts the alimentation (2) and the pontoon stops (5). The collected and compacted sludge starts to be dried (6), due a system of pipes which assure the circulation of the warm water. After being partially dry, the sediments are evacuated to be consumed into agriculture. The fibber glass tank is placed on pontoon, under the PV panels (10). The entire installation is automatic, being autonomic. After the evacuation is commanded the advance of the pontoon and the functioning cycle is reloaded.

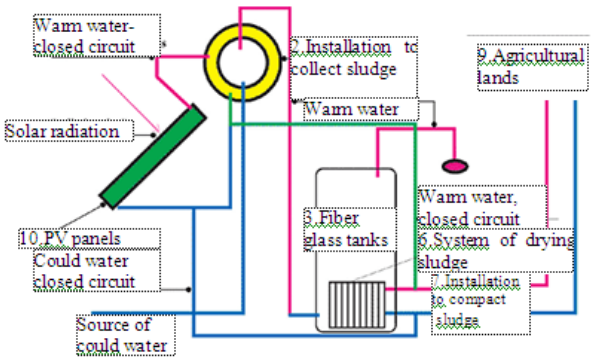


**Fig.8 - Schematic blocks of the installation**

Further are presented the main components of the prototype:

**PV with storage system**, Fig.9; the main advantage is the small weight of the system 18 kg+28kg for the panels and inverter, Power 1KW. The system is formed by an Off Grid 1 kW PV with energy storage in batteries recommended in areas where electricity is lacking. The package contains 2 x panels 500 W, 1 x inverter 24V / UPS system 1000 with 1 x Controller 60A 12-24V EP Solar, solar cable 20 ml 1 x 6mm x q 1 UV protection assembly system for panels 2 x MC4 connector kit 4-6mm cable connections dose 1 x 1 x switchboard cable seal safety and protection system for gel batteries 2 x 200Ah / 12V. Reliable modules are photovoltaic panels with great efficiency and high yield.

Even with a reduced incidence of light, the module achieves a good performance and yield due to excellent low light behaviour. Before and after lamination, each module undergoes an electroluminescence test. Performance guarantee: Up to 10 years: 90% of nominal output; Efficiency to 25 years: 80% of nominal power; the product warranty is 11 years for the Photovoltaic panel Polycrystalline 500W.

**Fig. 9 - PV Panels and storage**

Technical data: Maximum Power Pmax (W)=500 W, Voltage at Pmax (V) = 30,75V, Current at Pmax (A) = 8.34A, tensions empty (V) = 38,32V, short circuit current (a) = 8.83 = 1000V maximum voltage Nr. = 60 pieces of photovoltaic cells. The size of 156mm x 156mm size cell panel = 1.640x991, X=38 mm Weight = 18.0 Kg, 1000W inverter 24V. The transformation of alternating current to direct current is not provided by the electronic components but also through a robust integrated into the inverter transformer. For the inverter is assured management and control with a microcontroller with amplification, in combination with the "MOS-FET" technology. WT devices are one of the most reliable and robust worldwide.

OFF-GRID inverter is a professional device, designed for use in harsh conditions. Priority in the inverter consume is mainly for battery power until they reach their minimum voltage consumption. If they reach that minimum battery voltage inverter automatically switches the power supply. Power saving function inverter has automatic detection of the battery options. This method saves battery capacity and consumption in standby mode. The inverter is in standby mode power consumption of <2 watts. Overcharging batteries is prevented because the controller will stop charging when full capacity is reached. Solar controller is compatible with all brands of solar modules. The controller 12V-24V 60A is suitable for gel batteries and acid. The integrated microprocessor controls the charging switching thresholds of the precise and stable temperature. Features: The controller keeps the battery fully charged.

1. **System of collecting the sludge**

The collector is represented by a Screw Pump, Fig.10, with electric alimentation, aspiration pipe 55mm, and flow rated Q=25 ml/min, voltage: at request it can be at 110V or 220V, usage: dirty water with sediments or mug, Power 0.75kW, Hmax=80m, material stainless steel. It is special designed to aspire sediments or sludge from bottom of reservoirs or channels. On the deck, the sludge is deposited into a fibber glass tank, with a capacity of around 5 $m^3$. The hydraulic system of the collector is driven by a silent engine environmentally friendly, quite adapted to the specific area of the two Natural reservations.

The propellers proven to be durable and anti-winding ensure maximum prototype manoeuvrability in both directions, back and forth, even in shallow water with vegetation beyond measure.

**Fig. 10 - The sludge collector**

2. **Fibber glass tank**

It's provided with holes on lateral sides as a secondary filter and to eliminate as possible the water from the extracted sludge, Fig.11. Dimensions are 2540x 1960x980mm, to assure good deposition of the collected sludge. It is placed on the pontoon, under the PV-s.

**Fig. 11 - The fibber glass tank**

4. **System used to compact the sludge**

It refers to a small compression of sludge direct extracted from lake, before depositing it into the fibber glass tank. It is formed by a screw system (augers), Fig.12. The screw is moving through a conic portion and assures the sludge compacting.

**Fig. 12 - The compacting system**

The system is dedicated to the waste water, for mechanical waste water pre-treatment, screening, conveying, elevating, de-watering and compacting, sludge handling.

3. **System of partially dry the vegetation**

After the fibber glass tank is full-fill with sludge partially compacted the pontoon stops. At time interval, pre-selected in conformity with atmospheric parameters and local conditions, the compacted sludge starts to be dried due to the circulation of the warm water, through a system of small pipelines. The direct current generated by the solar modules feed directly the heating element and converted into useful heat with an electrical efficiency of 99%. There is no need to use an inverter. The system just consists of a heating element and a control system. This saves initial costs and maintenance.

After been partially dried the sludge is evacuated and deposited into a special sector till it will be transported to agricultural lands as fertiliser [11].

Besides the mentioned parts of the prototype there are some components which have been realised or bought for: interconnection [6], command from distance of the pontoon, sensor for detecting the full-fill of the fibber glass tank, automation of the start and stop of the pontoon, sensors for detecting the corresponding partially dry of the sludge, in accordance with atmospheric parameters (temperature, humidity).

## 6. CONCLUSION

The paper presents an innovative solution to collect and utilise the sludge from deposits into two lakes Natural Reservations, Lakes Techirghiol and Mangalia. The actual sludge is responsible for the perturbation of the ecological environment.

There were realized two prototypes for each lake; they represent a technical and scientific research challenge concerning designing, execution, automation, controlling and compacting systems, in accordance with environmental conditions imposed for these Natural Reservations. Last, but not the least they represent a solution that utilizes renewable sources, perfectly ecological, without disturb the local conditions.

Some other solutions used so far haven't been successful, because they have hastened the process of "suffocation excessive" with vegetation of these two lakes. The proposed solution eliminates the nutrient base for feed the vegetation and ensures the effective utilization of the sludge on agricultural lands, as biologic fertiliser. The region where the lakes are is well-known with soils less fertile and this sludge assures a supplementary ecologic, biologic possibility of increasing the soil productivity. Elaborated databases will allow further studies and researches.

The project aims to improve the environmental conditions, in accordance with appropriate standards at European level referring to protected areas [15], [16].

It has an actual and advance character and contains some new developed mathematical and numerical models in realization of the technical referential. The numerical model refers to interconnection of formative modules.

It also resolves the problem of influences between the developed vegetation and the organic deposits from lake, chemical characteristics of the water and not at least the benefit effects of the adopted solution in diminishing the shellfish, followed by the new conditions for fishery and for fish spawning. By restoring the fishery conditions and quality of water, the specific area for the previous mentioned birds will be rebuild.

No need to underline the importance of the quality of water into these two lakes taken into the analysis. Water influences the environmental health directly through chemical, biological and physical qualities, or indirectly through biological population that form one eco-system. Insufficient quantity of water leads to maintain unhealthy moods environment and damage the populations of wildlife (especially fishes, birds) and local flora.

The actual structure of sludge from Techirghiol lake is perturbed from its previous qualities. Sludge and water from Techirghiol Lake are used from the 19th century for their therapeutic spa qualities. This sludge is produced as a result of bacterial decomposition of aquatic organisms which have completed their existence, especially crustaceans Artemia salina and algae living in the water. Invasive new species of snails and clams, as a result of deterioration of water quality determine a dramatic increasing of the species characteristic from mentioned area, thereby reducing the therapeutic qualities of active sludge. It is important also for wintering of red breasted goose (Branta ruficollis), winter swan (Cygnus cygnus), great egrets (White Egretta), winter falcon (Falco columbarius), peregrine falcon (Falco peregrinus), polar loon (Gavia arctica), white cap ducks (Oxyura leucocephala), pygmy cormorants (Phalacrocorax pygmeus), species law protected.

In the period of migration, site waters are used by over 20.000 waders. For all these species it must be provided a stable ecosystem, in order to provide sustainable living conditions.

Both lakes will be monitored another five years, as to analyse the efficiency of this solution. Some new solutions, in direct connection, at suggestion of the Romanian Waters will be developed as to combat the excess vegetation from the hydropower lakes.

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