Ecological Mobile Solution for Reactivating the Sludge from the Natural Reservation Techirghiol Lake

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Abstract: In Romania there are two nature reserves with salt water, Mangalia and Techirghiol Lakes. They are currently facing new environmental issues. Their therapeutic mud, well known since the 19th century, has recently been affected by new deep-water streams. They occurred as a result of numerous local earthquakes of low intensity. The composition of water and saprophytic sludge changes due to their flow rate. Under these conditions, new species of freshwater-specific vegetation have developed, which has led to a complex process of eutrophication of the lakes. This produces a much faster vegetable sludge that disturbs the balance of the old active, saprophytic one. Experimental measurements performed during 2015-2018 illustrate the current environmental conditions, associated with the living conditions of birds and animals existing here, many of them protected by law. For the rehabilitation of the Techirghiol Lake, a prototype was implemented, currently being patented in Romania, and placed on a mobile pontoon powered by photovoltaic panels. He is able to collect and partially dry this newly developed mud. It is described its scheme as well as the main steps during an operating cycle. This model is suitable for nature reserves because it does not disturb the environment. The extracted sludge is additionally dried in specially arranged places to be used in agriculture as an organic fertilizer, to restore the quality of nearby agricultural land.

1 INTRODUCTION

In recent decades, the Black Sea area has faced unexpected problems caused by natural causes or by human interference. An increase in the number of small earthquakes recorded in deep waters has led to the appearance of freshwater streams, with low flow rate, but over time with significant consequences on the composition of the seawater in the area. These currents produce local erosion, followed by changes in the appearance of the coast).

The earthquakes were recorded mainly in the southern part of the coast, near the localities of Mangalia, 2 Mai, Techirghiol and Vama Veche. Techirghiol Lake is well known since the 19th century due to its therapeutic mud (Fioravanti and all, 2014).

Sand erosion and freshwater penetration affect the aquatic environment, causing changes in the characteristics of the activated sludge. The saprophytic mud with therapeutic effects rich in minerals has a very dense and oily appearance, being extracted from depth and used successfully in the treatment of rheumatism, anemia, rickets, spondylosis, hypothyroidism, neuromotor problems, skin, or endocrine disorders.

Fresh water enters especially the eastern part of Lake Techirgiol (Environmental Romanian Strategy, 2013-2030). In that area, the vegetation specific to fresh water but also resistant to semi-salt water appeared and developed excessively in the whole lake (Selman, 2007).

Salt water does not allow the sun to penetrate easily (Schinler, 2012). In this case, this excess vegetation rots quickly, turning into mud and overlaps the therapeutic one. Here, even in cold winters, the water never freezes, so this new rotten vegetation quickly produced the eutrophication of the lake. The local biological and chemical balance is

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affected due to the rapid and large-scale production of this type of sludge (Pullin and Andrew, 2012).

Therapeutic mud is formed as a result of bacterial decomposition of aquatic organisms such as seaweed and crustaceans Artemia salina, after the end of their natural life cycle (Mathew and all, 2020). This sludge is produced over a long period of time. Eutrophication sludge overlaps the active one, minimizing its concentration and therapeutic effects.

Since 2006 both lakes are registered as Nature Reserves, Ramsar Sites - Protected Areas, due to the specific vegetation and especially due to the birds that winter here or that pass and rest during the migration. More than 20,000 birds are recorded in Techirghiol Lake, some of them endangered species, now under the protection of the law (OUG, 2007).

The main objective of this research is to rehabilitate this ecosystem, without using classical solutions based on conventional fuel that produce noise and odor and that affect biological and aquatic life. Classical aggregates disrupt the nesting conditions, the proper reproduction of birds and animals, the rearing of chickens and their efficient feeding, both of certain local and migratory birds. Previously tested methods have not been shown to be effective.

This prototype is autonomous, made on a mobile pontoon powered by photovoltaic (PV) panels (Radulescu, 2019). Both lakes are located in an area with high solar radiation. The eutrophication sludge placed above the therapeutic one is relatively easy to collect. After collection, it is compacted and partially dried on the pontoon. This solution meets EU directives for the promotion of renewable resources in new technical solutions with environmental benefits.

This method allows the restoring the balance of active sludge and subsidiary an efficient, adequate and fast consumption of the extracted vegetable sludge, used as organic fertilizer in saline soils such as those in the Dobrogea area. The composition of the nutrient-rich sludge is perfectly organic to be used as a natural fertilizer in "green agriculture".

2 HYDROLOGIC CHARACTERISTICS

The problems in this area have required effective measures to protect nature reserves since 1982. In the last two decades, more than 80 earthquakes with an intensity of 3.0-3.8 on the Richter scale have been recorded. These, combined with excessive irrigation of agricultural land, to reduce the concentrations of nitrates accumulated during the communist period, led to the emergence of underground freshwater streams. They have led to a process of sweetening of the saline aquatic ecosystem.

The results, obtained by experimental measurements for Lake Techirghiol, are next illustrated. In order to minimize the infiltrations, dams were built in 1983 and 1989, mainly to protect the Mangalia shipyard but also the natural ecosystem. Currently, the lake water is divided into three areas, almost as separate entities. The first with salt water with 52-68 grams of salt per liter (g/l) located in the area closest to the sea, a saline area with 16-18 g/l as an intermediate area and an area with almost fresh water with 1-2.8 g/l, located near the locality Eforie Nord, Figure 1.

Figure 1: The Techirghiol Lake water structure with the specific areas and the current location of the therapeutic mud (black).

The active mud, sediment from Lake Techirghiol belongs to the group characterized as therapeutic estuary sludge. It is the product of complex long-term biological and chemical processes. The conformation of the lake basin, the available water currents and the phytoplankton determine the non-uniformity of the sludge area. The thickness range varies from a few centimeters to 2-3 m, structured in three layers.

Changes in the chemical composition of the lake water minimize the sludge reserves, which have decreased significantly in recent years. The physical-chemical composition of the sludge is a mixture of three phases:

- Solid phase, consisting of mineral and organic particles, of different sizes;
- Colloidal fraction composed of a mineral and organic substance such as mud;
- Liquid phase, consisting of an aqueous solution of soluble substances.

This solution softens and fills the gaps between the particles and the colloidal solid components of the sludge. To these components are added some microorganisms present in the sludge and decaying plant debris. Figure 1 shows the effective division into two parts of the mud from Techirghoil Lake, noted: A- therapeutic mud (black color) and B-

unusable sludge for human health. The general chemical composition of the sludge is:

- 69-71% humidity, based on natural sludge;
- Volatile substance from 6.4 to 7.21%;
- The rest, about 22-23% mineral sequence.

This area is now full of swampy vegetation, characteristic of fresh water. Due to heavy rains in 2005 and 2008, of about 230 l/m^2 recorded in 8 hours, and of approximately 270 l/m^2 in 7 hours, respectively, the water level in the freshwater area received a surplus of about 2.3 million cubic meters and about 2.5 million cubic meters, respectively, which allowed a significant increase in water levels throughout the lake by about 110-120 cm.
Additional fresh water was discharged into the intermediate brackish zone and from there shortly into the salt water zone.

As a result, since 2010, the specific freshwater and swamp vegetation has developed massively in almost all three areas of the lake, affecting local environmental conditions. Figure 1 illustrates the areas from which therapeutically active sludge can be collected, represented in black. The dark gray area represents areas with mixed saprophytic and vegetal mud, and the rest is covered by vegetation.

Between 2015 and 2018, a team of researchers consisting of chemists, biologists and engineers performed measurements on the quality and characteristics of water and mud, in all three areas, 20-25 cm above the bottom of the lake, in the sedimentation bed. Some of the results obtained are presented in Table 1, for aquatic and ecological data.

Table 1: Techirghiol Lake water characteristics.

	Min	Max	Av	SD
WL	4.02	4.21	3.24	0.11
SSD	0.43	1.17	0.83	0.29
TSM	12.7	49.8	29.1	14.1
TN	0.52	2.03	1.14	0.42
TDN	0.34	1.64	0.92	0.39
NH4+-N	0.055	0.51	0.242	0.137
TP	4.02	4.21	3.24	0.11
DTP	0.034	0.072	0.054	0.012
Chl-a	0.014	0.032	0.023	0.01
VPF	2.58	16.3	7.02	3.78

Where the notations are: Min - Minimum value, Max - Maximum value, Av - Average value, SD - Standard Deviation, WL- Water Level, SDD- Sediment Scattered Dosing, TSM -Total Suspended Matter, TN - Total Nitrogen, DTN-Dissolved total nitrogen, Ammonium-Nitrogen NH4+-N, TP - Total Phosphorus, DTP - Total Dissolved Phosphorus, Chl - Chlorophyll, and VPF- frequency of the pixel i in a set of n points, from the selected measurements.

Techirghiol Lake is the largest salt lake in Romania, with a length of 7,500 m, a maximum depth of 9 meters and a salinity of water with an average of 85-90 g/l. The qualities of mineralized salt water and saprophytic mud, used in the treatment of various diseases, make this place well known throughout the world. A sanatorium for treatment was opened in Techirghiol in 1899. In 1924, at the World's Fair in Paris, the sludge from Lake Techirghiol received the gold medal, thus recognizing its therapeutic effects.

Table 2 shows how the effective mineralization has evolved in the last 70-90 years. There is a permanent decrease in water salinity and recorded higher concentrations of magnesium, calcium and sulphate ions.

Table 2: Techirghiol Lake water characteristics.

Year	1936	1996	2014	2018
Salinity(g/l)	99.6	81.485	65.1	< 60

In the last two decades, Lake Techirghiol has undergone the most important changes in the composition of the water and, implicitly, in the characteristics of the mud. Table 3 illustrates some average values of the measurements, for water composition over the last decade.

Table 3: Water composition.

Nr	Indicator	2014	2016	2018
1	Fixed residue	55844.22	62447.42	66780.12
2	CBO_5	7.87	8.16	9.05
3	CCOMn	34.57	39.17	41.01
4	O_2 dissolved	8.61	7.84	6.86
5	Ca_{2+}	202.24	221.82	240.4
6	Mg_{2+}	2369.32	2571.34	2777.4

3 ENVIRONMENTAL AND BIOLOGICAL CONDITIONS

The invertebrate fauna that inhabits the lake is dominated by the saline crustacean Artemia, which together with the crystalline alga Cladophora provides the raw material for the production of saprophytic sludge. Its active mineral components give it a special therapeutic value.

In such diverse local conditions, the vegetation resembles the marine one, being present halophilous species such as Salicornia europaea, Artemisia santonica, etc. Among the species mentioned, the brown alga Cystoseira Barbata Sueda salsa the sea

grass due to chemical changes of water are endangered species, along with four other species of invertebrates and five species of fish.

The vegetation has developed and adapted continuously. Habitats and wetlands with coastal features ensure good development conditions for a wide variety of species.

The high salinity of the lake and the constant wind that mixes the water (nearby is the Black Sea) make the lake never freeze and be attractive to migratory or wintering birds. Approximately 150 species of local or transit birds are known, reaching over 20,000 specimens during migration. Among them are many endangered protected species such as Copper Duck - Oxyura leucocephala, red-necked goose - Branta ruficollis (one of the rarest species of geese on the planet), winter swan, white caliph -Tadorna tadorna, curly pelican, black-headed gull-Larus melanocephalus, pelican, etc.

In Figure 2 are illustrated some of the birds here mentioned: red-breasted goose, Mediterranean gull, curly pelican, white caliph, great crested grebe and great flamingo.

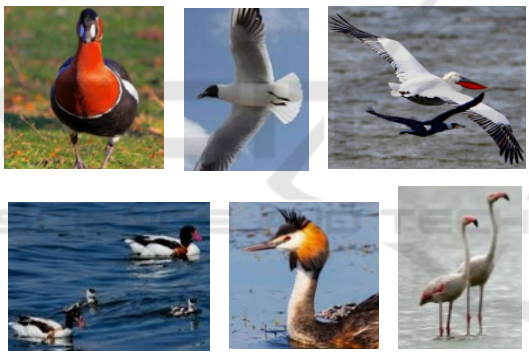

Figure 2: Some protected birds from Lake Techirghiol.

According to recent data, Lake Techirghiol is important for the wintering of many species of birds, but also for the species that nest here. For all birds, seaweed, sea crustaceans, sea fish, frogs or small snakes are the main sources of food. The dense growth of algae and other aquatic plants covering over 25% of the surface interferes with the normal biological ecosystem and certainly affects the life of birds. Green plants produce oxygen in the sunlight, but consume oxygen at night. Due to their excessive development, the percentage of dissolved oxygen in the water has decreased massively, and the fish have become weaker or in some cases in hot summers have died by suffocation.

Artemia Salina is the main filter in Techirghiol Lake, which together with Cladophora have an important role in increasing the phosphorus level. But it is the mud that brought fame to this lake. It is the chemical and biochemical product suffered by the minerals and organic substances in the lake.

Lake Techirghiol has undergone significant changes in water levels and, therefore, its salinity in recent decades. Decreased salinity is harmful in this case. Under these conditions, the therapeutic mud recovers with difficulty. Therefore, it is necessary to intervene to remove the sludge deposited much faster and which significantly affects the quality of saprophytic sludge.

4 THE IMPLEMENTED SOLUTION

The solution next presented has been implemented and tested since 2018 in Techirghiol Lake. In the meantime, several improvements and automations have been made to it to be better adapted to its utilization in nature reserves. Figure 3 illustrates the main components of the model, in a perfectly ecological version. It is made on a mobile pontoon powered by two photovoltaic panels (noted 10) equipped with a storage system, of 24 V/UPS inverter with 60A 12-24V EP solar controller, plus mounting and fixing accessories.

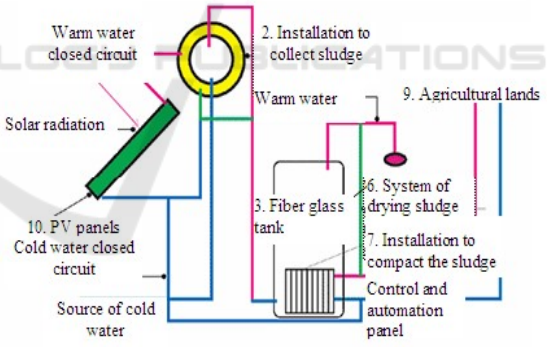

Figure 3: The main components of the prototype.

Next, the main steps are mentioned for an operating cycle. The prototype advances by propulsion, commanded by automation from the lake shore (represents Step 1). The sludge is collected by a screw pump (Step 2) provided with a suction pipe with a diameter D = 55 mm, having a flow rate Q=25 l/min and power P = 0.75 kW. It is a stainless steel pump recommended for sediment or sludge-laden liquids as in this case (noted 2). The low flow rate variant was selected so as not to disturb the deposited sludge.

Only the eutrophication sludge deposited over the mineral sludge is extracted from the bottom of the lake. The aspirated sludge is introduced into a compaction system (noted 7) to remove excess water (Step 3). Compaction is done by a screw system that rotates in a conical portion of the suction pipe. The sludge is then deposited in a fiberglass tank (noted 3) with a capacity of approximately 0.6 m^3 (Step 5), placed on the pontoon under PV-s.

The fiberglass tank has small holes in its upper part to allow the release of a quantity of the extracted and decanted water. It also ensures proper storage of the extracted sludge. Mud is collected until the level and weight sensors stop the pontoon from moving and supplying it with sludge (Step 6).

From this point on, the sludge is partially dried through a system of thin pipes through which hot water flows, placed on the bottom of the fiberglass tank (note 7). When the weight of the sludge is about 60-70% of its initial value, it is considered partially dry, (Step 7) and it is discharged (Step 8). This sludge partially s dried sludge is stored in special places until final drying is ensured. After emptying the fiberglass tank, a new cycle can begin. The control system of the pontoon motion, automation that stops the pontoon when the fiberglass tank is sufficiently filled with mud, automation system that coordinates the entire cycle and finally the system of power supply from photovoltaic panels or storage of energy in batteries when the model do not function are designed separately.

5 CONCLUSIONS

The prototype can be moved on request in different areas of the lake, the rest remaining completely unaffected. Being a quiet system, it does not disturb the life of the birds. Functioning without using classic fuel and therefore without producing an unpleasant odor, the installation can be used in nature reserves. Being mobile, it can move in areas where there are no bird nests, thus maintaining the biological ecosystem.

The extracted sludge is a natural fertilizer, full of nutrients. It can be used on agricultural lands to restore their optimal properties and characteristics, in order to improve the obtained quantities of agricultural crops.

By additional drying of the sludge, the time until its utilization is shortened.

Thus, this solution has a double benefit. First of all, the sludge produced by eutrophication is extracted, restoring the chemical balance of the therapeutic sludge in the places where the prototype is implemented. Secondly, an efficient consumption of the extracted sludge is ensured, as a fertilizer in the salty soils of Dobrogea.

In the last years of implementation, by collecting the eutrophication sludge, the surface from which the therapeutic sludge could be collected increased by about 8%.

The solution implemented in 2018 does not affect the life, reproduction and nesting of birds. Many birds were spotted near the pontoon, eating and resting in the sun.

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REFERENCES

Fioravanti, A., et all, 2014. *Short- and long-term effects of mud-bath treatment on hand osteoarthritis: a randomized clinical trial*, In Journal Biometeorology, vol. 58, issue 1. doi: 10.1007/s00484-012-0627-6.

Romanian Environmental Strategy, 2013-2030. http://www.mmediu.ro/beta/domenii/dezvoltaredurabila/strategia-nationala-a-romaniei/.

Selman, A., 2007. *Eutrophication an Overview of Status, Trends, Policies, Strategies*. World Resources Institute.

Schinler, David, W, 2012. *The dilemma of controlling cultural eutrophication of lakes*, In Biological Science, The Royal Society. vol. 279, issue 1746, ISSN: 14712954, https://doi.org/10.1098/rspb.2012.1032.

Pullin, I., Andrew S., 2012. *Eutrophication of Lakes and Rivers*, Wiley Online Library. https://doi.org/10.1002/9780470015902.a0003249.pub2.

Mathew, M.M, et all, 2020. *Sustainable and eco-friendly strategies for shrimp shell valorization*, Environmental Pollution, Elsevier. vol. 267, issue 115656.

O.U.G. 57, 2007. Government Emergency Ordinance on Protected Natural Areas.

Radulescu, V., 2019. *A pilot station using renewable resources to rehabilitate the inefficient small-hydro power plants*, IOP Conference, vol. 564, issue 012138.