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Research Article

The influence of abiotic factors on suppliers of organic matter in the peloidogenesis process from Lake Techirghiol, Romania

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Abstract. The purpose of the study was the determination of the current situation of the Techirghiol ecosystem which is unique in Romania because of its hypersaline character and because of the large productivity in the formation of the sapropelic mud with therapeutic properties. A number of 107 taxonomic units have been identified in the phytoplankton. Most of the algae species belong to the diatoms group, followed in descending order by representatives of Chlorophyceae, Dinophyceae, Euglenophyceae, Chrysophyceae, Cryptophyceae and Xantophyceae. The number of taxa identified in the phytoplankton varied inverse proportionally with the water mineralization degree, unlike the values of the phytoplanktonic biomass, that have risen along with the water salinity. The high concentrations of Cl^- and SO_4^{2-} ions have been associated with a diverse phytoplankton and superior values of the microalgae biomass only in the year 2007. The report of the $Na^+ > Mg^{2+} > Ca^{2+}$ cations, generally valid for any sampling point, has created optimal conditions for the development of the phytoplankton, and especially the calciphilic alga *Cladophora crystallina* (Roth) Kütz. The concentrations of the nitrogen compounds ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$) have been sufficient for the insurance of the nutritional necessities of the phytoplankton, especially for the diatoms that have registered the highest diversity and the highest biomass along microalgae.

Key Words: salt, lake, algae, mud, biomass.

Rezumat. Scopul studiului a fost determinarea situaţiei actuale a ecosistemului Techirghiol, unic în România prin caracterul hipersalin şi prin marea productivitate în formarea nămolului sapropelic cu proprietăţi terapeutice. S-a identificat compoziţia fitoplanctonului din lacul Techirghiol în anii 2004, 2007, 2009 şi 2010 (prin evaluarea numărului de specii şi a biomasei lor) dar şi influenţa variaţiilor factorilor hidrochimici asupra acesteia şi, implicit, asupra potenţialului peloidogenetic al acestui lac. În fitoplancton s-au identificat 107 unitaţi taxonomice. Majoritatea speciilor de microalge au făcut parte din grupul diatomeelor, urmate în ordine descrescătoare de Chlorophyceae, Dinophyceae, Euglenophyceae, Chrysophyceae, Cryptophyceae and Xantophyceae. Numărul taxonilor identificaţi în fitoplancton a variat invers proporţional cu gradul de mineralizare al apei, spre deosebire de valorile biomasei fitoplanctonice, care au crescut odată cu salinitatea apei. Concentraţiile mărite ale ionilor de Cl^- şi SO_4^{2-} s-au asociat cu un fitoplancton diversificat şi cu valori superioare ale biomasei microalgelor doar în anul 2007. Raportul cationilor $Na^+ > Mg^{2+} > Ca^{2+}$, general valabil pentru orice punct de prelevare, a creat condiţii optime pentru dezvoltarea fitoplanctonului şi, în special, a algei calcifile *Cladophora crystallina* (Roth) Kütz. Concentraţiile compuşilor cu azot ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$) au fost suficiente pentru asigurarea necesităţilor nutritionale ale fitoplanctonului, în special pentru diatomee care au înregistrat cea mai mare diversitate şi cea mai mare biomasă dintre microalge.

Cuvinte cheie: sărat, lac, alge, nămol, biomasă.

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Introduction

The important role of algae in the salt water ecosystems is well known, they contributing to the biological balance and representing the basis of the primary productivity in aquatic basins. They are involved in water purification, mud formation and offer the oxygen needed in the process of respiration (Doroftei *et al* 2010). Nowadays, many scientists from around the world try to find solutions not only for the exploration, but also for the exploitation of this valuable marine flora and other marine related natural resources in various activity domains, for the benefit of mankind (Charlier & Chaineux 2009; Sava *et al* 2009; Silaghi *et al* 2011).

Lake Techirghiol, a fluvial marine bank type of lake, situated in the south-east region of Romania, on the Black Sea littoral, enters the category of pelogenous lakes, in which mud with therapeutic properties is formed, used empirically at the beginning, in an unorganized mode, though gradually being proven the effect it has in the maintaining and improvement of health (Gheorghievici 2010; Kerkmann 2010).

The catchment area of Lake Techirghiol is of 150 km^2, the water volume is 4.18 mil.m^3 and the maximum depth 9.75 m.

The water supply resources of the lake are ensured by both the superficial discharge and the underground water contribution. It is also supplied by the shore springs (sources), which bring and amount of fresh water, active mostly at the back of the lake (Environment Report, Techirghiol City Hall, 2009).
The lake water from Techirghiol is highly concentrated, brominated, chorinated, sodic, hypertonic (Testing Report no. 350/03.08.2010, I.N.R.M.F.B.).
The cenosis of this lake are poor as a number of species, but rich as a number of individuals. Through the decomposition (mainly anaerobic) of the rich vegetal and animal biomass, the formation of salted peloid deposits is reached, which is used with success in balneotherapy (Godeanu 2002).
The purple water, described by Olga Bonciu in 1955 and 1957 on the shore of Lake Techirghiol (Bonciu *et al* 1963) and I. Ţuculescu in 1965, biotope that contained numerous sulfur autotrophic photosynthetic bacteria (species of *Cromatium, Rhabdocromatium* and *Thiopolycoccus*) and had represented one of the most productive factors in the genesis of the mud (Samson *et al* 1984), has disappeared. It was not present on the entire surface of the lake, during the development period of the study (2004, 2007, 2009, 2010).
The important phenomenon that interfered in the life of Lake Techirghiol was either a concentration of the water due to the physical and geographic particular conditions (being the only littoral lake that does not communicate at the surface with the Black Sea), or a decrease of the mineralization of the water and even the mud, due to the inflow of fresh water in the lake. The variations of the mineralization level of the lake water, the imbalances from the ecosystem induced by the anthropic factor through the uncontrolled utilization of the north part of the lake with salted water, for bathing and those provoked by the abiotic factors (precipitation, wind, discharge of fresh water), have diminished the pelogenous potential of the lake through the decrease of the biomass contribution of the main providers of organic materia for the formation of mud, *Cladophora crystallina* (Roth) Kütz and *Artemia salina* L.
In 1931, when macrophytic alga *Cladophora* has disappeared, due to the water salinity of 110 g•dm^{-3} and the water density that has decreased from 1.075-1.076 g•cm^{-3} to 1.060-1.065 g•cm^{-3}, the pelogenous capacity of lake Techirghiol has been questioned, although Paul Bujor sustained that, in lack of species of the *Cladophora* type, and therefore of the organic substance that can produce hydrogen sulfide through its putrefaction, mud can still be formed through the reduction of the sulfates (Bujor 1928).
On the other side, the utilization of the sulfur sapropelic mud, highly hydrated, with aqueous, chlorinated, sodic magnesiac solution (Analysis Report I.N.R.M.F.B./05.10.2010), in the treatment of different diseases (rheumatism diseases, gynecological diseases, diseases of the central and peripheral nervous system, respiratory diseases etc), which is used in Techirghiol Balneary Sanatorium and also in other balneary stations from Romania (Bavaru *et al* 2011), has lead to the graduate depletion of the mud reserves and also to the modification of the characteristics of the ecosystem that generates it.
For the conservation of the aquatic ecosystem Techirghiol and the assurance of the continuity of the necessary conditions for the achievement of the peloidogenesis process, and also for the regeneration of the used mud returned in the lake, actions have been initiated for the protection and improvement of the ecosystem through legislative and institutional measures; lake Techirghiol has been designated protected natural area of national interest (Law 462/2001), Ramsar site (2006) and Water Direction Dobrogea has elaborated a management plan of the Protected Area Lake Techirghiol 2008-2013 (www.scribd.com/doc/37636154/Draft-Management Plan of the Protected Area Lake Techirghiol 2008-2013).
As a consequence, such lakes as lake Techirghiol, require the maintenance of some biological, chemical, limnogenetical, limnogeological, morphometrical standards, which may be different from the general recommedations for freshwater and saline lakes, but non-therapeutical (Bulgăreanu 1996; Poplăcean 2010), because it has been observed a differentiation between the plankton, microbenthos, macrophytes and cormophytes species present in the pelogenous lacustrine ecosystems (usually therapeutic) and the non-pelogenous ones (Ionescu *et al* 1998; Vincze *et al* 2011).

Material and Methods

The study was conducted in the years 2004-2010 in the north east side of lake Techirghiol with salt water, where peloidogenesis process is intense, from three stations. A number of 45 samples of phytoplankton (5 parallel samples/ sampling point/ year) from surface layer (1m depth) were filtered with planktonic net, Wisconsin type, n020. The concentrated samples were introduced in plastic containers, preserved immediately with Lugol solution (a proportion of 3 mL of fixing solution for 1000 mL of sample), and then labeled. The algological material was analyzed on a Fuchs-Rosenthal chamber; for accuracy, three duplicate counting were made in chamber (both the upper and the lower chamber) for each sample of phytoplankton. Algal species were determined in accordance with Van Landingham (1982), Anagonstidis & Komárek (1988), Kramer & Lang-Bertalot (1988), Sládeček (1989), Prescott *et al* (1996), Godeanu (2002), Pârvu (2003), Sigee (2005), Anastasiu (2008), Hamed (2008), Zgrundo *et al* (2009).
For the estimation of the microalgae biomass, the individual volumes of cell (μm^3) and biomass as wet weight (mg•dm^{-3}) for each species were calculated according to approximate geometrical figures (Hillebrandt *et al* 1999).
Macrophytes were sampled after transects method (I.E.P, Wiser D3.2-1, 2009) using 0.25 m^2 enclosure system. Biomass dry weight of 120 samples (20 sample/ transects; 3 transects/ sampling point) was determined after filamentous thalli were dried at 75°C for 48 hours (Sfriso *et al* 1991) and weighed. The abundance for each taxon was calculated as the number of cell per cubic decimeter.
Samples for the hydrochemical analysis have been taken in the same time and from the same locations as the phytoplankton samples; the pH has been determined electrometrically, with pH primary standard solutions, the dissolved oxygen has been determined through the Winkler method, and the SO_4^{2-} ion by gravimetric method with barium chloride solution in acid medium (HCl). The chlorine concentration has been determined through the volumetric method with $AgNO_3$, in the presence of the ferric alum indicator, in acid medium (HNO_3), the Ca^{2+} and Mg^{2+} ions through complexometric method, and Na^+ flamephotometric (JENCONS spectral device). HCO_3 has been determined volumetric, in the presence of metilorange indicator.
For the determination of the pollution microbiological indicators water samples have been taken in sterile recipients, according to SR EN ISO 19458:2007; the membrane filtration

method has been utilised according to SR EN ISO 6222:2004 for the identification of the total number of bacteria that develop at 37°C, SR EN ISO 9308-1:2004 for the coliform bacteria and *Escherichia coli*, SR EN ISO 7899-2:2002 for the intestinal enterococci. Results were expressed as colony forming units (CFU) per 1 cm^3 or 100 cm^3 of water.

Results

The structure of the phytoplankton in lake Techirghiol in the years 2004, 2007, 2009 and 2010, has been diverse, a number of 69 taxa being identified and organised in 8 classes (Table 2). Diatoms (Bacillariophyceae) present the highest diversity (63 taxa), being followed by Chlorophyceae (23 taxa), Cyanobacteria (21 taxa), Dinophyceae (9 taxa), Euglenophyceae (6 taxa), Chrysophyceae (3 taxa), Cryptophyceae (2 taxa), and Xantophyceace being represented by only one taxon.

Diatoms and Cyanobacteria were the groups with the highest diversity from the phytoplankton. From the Bacillariophyceae, the Pennatae subclass was represented in lake Techirghiol by 13 species of the *Nitzschia* genus, and 10 species of the *Navicula* genus.

The *Pinnularia, Surirella, Amphora, Achnanthes, Cocconeis* genera have been identified with three species each, R*hopalodia, Stauroneis, Gyrosigma, Fragilaria, Cymbella* with two species each, and *Rhoicospaenia, Synedra, Amphiprora, Gomphonema, Diploneis, Caloneis* have included only one species. From the subclass Cetricae, only three types have been identified: *Thalassiosira, Melosira* with two species and *Cyclotella* with one species.

From the Chlorophyceae class, 27 genera have been identified in the plankton, most of them being represented by only one species *(Asterococcus, Carteria, Chlamydomonas, Dictyosphaerium, Dunaliella, Gonium, Keratococcus, Oocystis, Pediastrum, Scenedesmus, Schroederia, Selenochloris, Ulotrix, Urospora*), an exception being made by *Chlorella* and *Cladophora*, which have included two species. The *Enteromorpha* genus has proven maximum diversity in the green algae groups, and was present in the plankton of lake Techirghiol by three species (see Table 1).

For the determination of time and space variability of the structure of the phytoplankton, the Shannon index and the Margalef index have been calculated; the evaluation of the variability of the phytoplankton's structure from Lake Techirghiol is presented in Table 2.

The numeric abundance of the microalgae in the years 2004, 2007, 2009, and 2010 has varied between $1.1•10^3$ and $1.9•10^6$ cells•dm^{-3} (with a medium value of $8.3•10^4$ cells•dm^{-3} (see Table 3), and the wet biomass from 0.002 to 10.4 mg•dm^{-3} (medium value being 1.23 mg•dm^{-3}) (see Table 4).

The most frequently identified species in the phytoplankton from lake Techirghiol between the years 2004-2010 have been *Fragilaria ulna* (Nitzsch) Lange-Berthalot (52.48% in the Sanatorium prelevation point, in 2010), *Amphora coffeaformis* var. acutiuscula (Kütz) Hustedt (51.67% in the Boathouse prelevation point, in 2009) and *Navicula salinarum* Grunow (40.57% in the Sanatorium prelevation point, in 2004).

The microalgae density has registered values in the interval $1.8•10^4$ (2010) – $1.9•10^6$ (2007) cel•dm^{-3}; these values are close to the ones recorded in 1977 – $7.1•10^5$ cel•dm^{-3} (Trică 1977), but inferior to the existing data in bibliography from the period 1976-1982 (Trică 1988), when there have been determined values of 109-1010 order. There is a similarity between the present and anterior data (Ţuculescu 1965) only for the biotop-water shore with green algae.

The *Cladophora* population from lake Techirghiol has its origins in the marine flora of the golfs that gave birth to the littoral lake with a salinity of de 14-16 g•dm^{-3}, flora which was similar to the one existing in the Black Sea. As a consequence of the intense evaporation and the semi-arid climate, the salinity of lake Techirghiol grew a lot because of the accumulation of mineral salts, macrophytic green alga *Cladophora* passing through an adaptation process.

At first, the *Cladophora* population has diminished its biomass, until the year 1931 when it totally dissapeared, in the same year, the lake water salinity reaching record values of 110 g•dm^{-3}.

In the year 2007, we have calculated a medium dry biomass of the *Cladophora* species in the Sanatorium point of the littoral zone of 536.2 g•m^{-2} , and in the year 2009, also in the littoral zone but in the Boathouse point, the medium dry biomass of the *Cladophora* was of 328.6 g•m^{-2} (see Table 4).

The most representative anions for lake Techirghiol are Cl^- and SO_4^{2-}, the concentration of the chlorine ion has varied between the interval 30.77 g•dm^{-3}- 34.38 g•dm^{-3}, from one sampling point to another, demonstrating a good homogenity on an horizontal gradient (see Table 5).

The SO_4^{2-} has registered a maximum concentration in the Tower TV sampling point from the central part of the lake, its concentration variations being a result of the distribution mode of the organic matter and the densities of the bacterial populations in the pelogenous zone of the lake.

The HCO_3 ions proves the afflux of fresh water in lake Techirghiol; it has presented an unspectacular variability on all three sampling locations, determined by the biological processes.

The main cations (Na^+, Ca^{2+}, Mg^{2+}) have manifested a limited dynamics of the concentrations in the analyzed sampling points, following the one of the anions to which it relates.

The distribution of the ammonium nitrogen (N-NH_4^+) shows a reduced spatial or temporal variability; in Tower TV sampling point, in the year 2010, even becoming analytically undetectable. In reverse, the concentration of the nitrate nitrogen (N-NO_3^-) varied more in time (with maximum values in 2010), and less in space (except for the year 2007).

The dissolved oxygen presented a concentration over 5.00 mg•dm^{-3} in the sampling point from the central part of the lake, in inferior values in the littoral sampling points Sanatorium and Boathouse, where there are bathing areas and numerous clumps of *Cladophora*. The oxygen saturation of the lake water has registered values under 50% in the years 2004 (37.55%) and 2007 (26.32%) and above 50% in the years 2009 (51.52%) and 2010 (62.84%).

Discussion

It can be concluded that the pronounced prevalence of the diatoms was typical for the phytoplankton of lake Techirghiol in all of the studied years. In medium, the Bacillariophyceae have contributed with 54.08% to the total specific diversity, their prevalence being maximum (70%), in June 2007, and a bit reduced in the years 2010 (52.63%), 2009 (50.94%), and 2004 (45.76%).

Table 1a. The qualitative composition of the phytoplankton in Lake Techirghiol 2004, 2007, 2009, 2010.

Taxa	May 2004		June 2007		June 2009		June 2010		
	S	B	S	B	S	B	S	B	T
Euglenophyceae									
***Euglena pisciformis* Klebs**	+	-	+	+	-	-	-	-	+
***Eutreptia viridis* Perty**	-	-	+	+	+	-	-	-	-
***Trachelomonas euristoma* Stein**	-	-	+	+	-	-	-	-	-
***T. hispida* (Perty) Stein em. Deflandre**	-	+	+	+	-	-	-	-	-
***T. incerta* Lemmermann**	-	-	+	+	-	-	-	-	+
***T. regularis* Skvortzov**	-	-	+	+	-	-	-	-	-
Bacillariophyceae									
***Achnanthes brevipes* (Agardh)**	-	-	+	+	+	-	+	-	+
***A. lanceolata* var. elliptica Cleve**	-	-	+	+	-	-	+	-	-
***A. longipes* (Agardh)**	-	-	+	+	-	+	-	-	-
***Amphiprora paludosa* W.Sm.**	-	-	+	+	-	-	-	-	-
***Amphora coffeaformis* (Agardh)**	+	-	+	+	-	-	-	+	-
***A. coffeaformis* var. acutiuscula (Kütz) Hustedt**	-	++	+	+	-	+++	+	+	+
***A. commutata* Grűnow**	-	-	+	+	+	-	+	-	-
***Caloneis amphisbaena* (Bory) Cleve**	+	-	-	-	-	-	-	+	-
***Cocconeis pediculus* (Ehr.)**	-	-	+	+	+	-	+	-	+
***C. placentula* (Ehrenberg)**	+	-	+	+	-	-	-	-	-
***C. scutellum* (Ehrenberg)**	-	-	+	+	-	-	-	-	+
***Cyclotella meneghiniana* Kützing**	-	-	+	+	+	+	-	-	-
***Cymbella gracilis* (Rabenh) Cleve**	-	-	+	+	-	-	-	+	+
***C. ventricosa* (Kützing)**	-	-	+	+	-	-	-	-	-
***Diploneis interrupta* (Kütz.) Cleve**	-	-	+	+	-	-	+	-	+
***Fragilaria fasciculata* (Agardh) Lange-Berthalot**	-	-	+	+	+	-	-	+	+
***F. ulna* (Nitzsch.) Lange-Berthalot**	+	-	+	+	-	++	+++	++	++
***Gomphonema angustatum* (Kütz.) Rabenhorst**	-	-	+	+	-	+	-	+	-
***Gyrosigma spenceri* W. Smith (Griffith & Henfrey)**	+	-	+	+	-	+	-	+	+
***G. strigile* (W. Smith) Cleve**	-	-	+	-	-	-	-	+	-
***Melosira moniliformis* (O. Müller) Agardh**	+	-	+	+	-	-	+	+	-
***M. moniliformis* var. subglosa Grunow**	-	-	+	+	-	-	-	-	-
***Navicula cincta* (Her.) Kütz**	+	+	+	+	-	-	+	+	+
***N. cryptocephala* Kützing**	-	-	-	-	+	+	-	+	+
***N. exigua* (Greg.) O.Müller**	-	-	+	+	-	-	-	+	-
***N. hennedyi* W. Smith**	+	+	-	+	-	-	-	-	-
***N. menisculus* Schumann**	-	-	+	+	-	-	+	-	-
***N. placentula* (Ehr.) Grunow**	-	-	+	+	-	-	-	+	-
***N. placentula* (Ehr.) Grunow var. rostrata A. Mayer**	-	-	+	+	++	-	-	-	+
***N. pupula* Kützing**	-	-	+	+	+	+	-	+	-
***N. rhyncocephala* Kütz.**	-	-	+	+	-	-	+	-	+
***N. salinarum* Grunow**	++	-	+	+	-	-	-	-	+
***Nitzschia apiculata* (Greg.) Grunow**	-	-	+	+	-	-	-	-	+
***N. acicularis* Kützing Smith**	-	-	+	+	-	+	+	+	-
***N. closterium* (Ehr.) W. Smith**	+	-	-	+	-	-	+	-	+
***N. distans* Gregory**	-	-	+	+	-	-	-	-	+

Table 1b. The qualitative composition of the phytoplankton in Lake Techirghiol 2004, 2007, 2009, 2010.

Taxa	May 2004		June 2007		June 2009		June 2010		
	S	B	S	B	S	B	S	B	T
N. lanceolata **W. Smith**	-	-	+	+	-	-	-	-	-
N. longissima **f. parva Grunow**	-	-	+	-	+	-	+	-	-
N. longissima **var. reversa Grunow**	+	+	+	+	+	+	+	+	-
N. lorenziana **Grunow**	-	+	+	-	+	-	-	+	-
N. recta **Hantzsch**	-	-	+	+	-	-	-	-	+
N. subtilis **(Kütz.) Grunow**	+	+	-	-	-	-	-	-	-
N. tryblionella **Hantzsch**	-	-	-	-	+	+	+	+	-
N. tryblionella **var. victoriae Grunow**	+	+	+	-	-	-	-	-	-
Pinnularia microstauron **(Ehr.) Cleve**	-	-	-	+	+	+	+	+	+
P. microstauron **var. ambigua Meister**	+	+	+	+	+	+	+	-	+
P. viridis **(Nitzch) Ehr.**	-	-	+	-	-	-	-	-	+
Pleurosigma angulatum **(Queck) W.Smith**	+	+	-	-	+	-	-	-	+
P. angulatum **var. strigosum (W.Sm.) Cleve**	-	-	-	-	+	+	-	-	-
P. delicatulum **W. Smith**	-	-	-	+	-	-	-	-	-
P. elongatum **W. Smith**	+	+	-	-	-	-	-	+	-
Rhoicosphaenia curvata **(Kütz.) Grunow**	+	+	-	-	-	-	-	+	-
Rhopalodia gibba **(Ehr.) O. Muller**	-	+	-	-	-	-	-	-	-
R. gibba **var. ventricosa (Ehr.) Grunow**	+	-	-	-	-	+	-	-	-
Stauroneis anceps **(Ehr.)**	-	-	-	+	-	-	+	-	-
S. salina **W. Smith**	-	+	-	+	-	+	-	-	+
Surirella ovata **Kützing**	+	+	+	+	+	-	-	-	-
S. spiralis **Kützing**	+	-	-	-	-	-	-	-	-
S. striatula **Turp.**	-	+	-	-	-	+	-	-	-
Synedra tabulata **(C. Agardh) Kütz.**	+	+	+	++	+	+	+	+	+
Thalassiosira excentrica **(Grun.) Jorg**	-	-	+	+	-	-	-	-	-
T. parva **Pr.-Lavrenko**	-	+	-	-	+	-	-	-	-
Chlorophyceae									
Asterococcus superbus **(Cienkowski) Sherfell**	-	-	+	+	-	-	-	+	-
Carteria multifilis **(Fres.) Dill.**	-	-	-	-	+	-	-	-	-
Chlamydomonas incerta **Pascher**	-	-	+	-	-	-	-	-	-
Chlorella ellipsoidea **Gerneck**	-	+	+	+	-	+	-	-	-
C. vulgaris **Beyerinck**	-	-	+	+	+	-	-	-	-
Cladophora crystallina **(Roth) Kütz.**	+	+	-	-	-	+	+	+	-
C. vagabunda **(L.) Hoek**	+	+	+	+	+	+	+	+	-
Dictyosphaerium ehrenbergianum **Nagela**	-	-	-	-	+	-	-	-	-
Dunaliella salina **Teodoresco**	+	+	-	-	+	+	-	-	-
Enteromorpha intestinalis **(L.) Link**	-	-	-	+	-	-	+	-	-
E. linza **(L)J. Agardh**	-	-	+	-	+	-	-	-	-
E. maeotica **Pr.-Lavrenko**	+	+	+	-	-	-	-	-	-
Gonium pectorale **O. F. Műller**	-	-	+	+	-	-	+	-	+
Keratococcus suecicus **Hindak**	+	-	-	-	-	-	+	-	-
Oocystis elliptica **W. West**	+	+	-	-	+	-	-	-	-
Pediastrum tetras **(Ehrenberg) Ralfs**	-	-	+	-	-	+	-	+	-
Rhizoclonium hieroglyphicum **(Ag.) Kűtzing**	-	+	-	-	-	-	-	-	-
R. riparium **(Roth) Kűtz. ex.Harv.**	+	+	+	+	-	-	-	+	-
Scenedesmus quadricauda **(Turp.) Brébisson**	+	+	-	-	-	-	+	+	+
Schroederia setigera **(Schröd.) Lemmermann**	+	+	-	-	-	-	+	+	-

Table 1c. The qualitative composition of the phytoplankton in Lake Techirghiol 2004, 2007, 2009, 2010.

Taxa	May 2004		June 2007		June 2009		June 2010		
	S	B	S	B	S	B	S	B	T
Selenochloris bicaudata **Pascher**	-	-	-	-	+	+	-	-	-
Ulotrix zonata **(Weber & Möhr) Kűtz.**	+	+	-	-	-	-	+	-	-
Urospora penicilliformis **(Roth) Areschoug**	+	-	-	+	-	-	+	-	-
Chrysophyceae									
Chrysamoeba scherffelli **(Pascher) Matvienko**	-	-	+	+	-	-	-	-	-
Dendromonas cryptostylis **Skuja**	+	-	+	-	-	+	-	-	-
Desmarella moniliformis **Kent**	+	-	-	-	+	-	-	-	-
Cryptophyceae									
Chroomonas caudata **L. Geitler**	-	-	-	+	-	-	-	-	-
Chryptomonas ovata **Ehrenberg**	-	-	-	-	-	+	+	-	-
Xantophyceae									
Gloeobotrys chlorinus **A. Pascher**	-	-	+	-	-	+	-	-	-
Dinophyceae									
Amphidinium klebsii **Kofoid et Swezy**	-	-	+	+	-	-	-	-	-
Glenodiniopsis steinii **Woloszynska**	-	+	+	+	-	-	+	-	-
G. uliginosa **(Schilling) Woloszynska**	-	-	-	-	+	-	-	-	-
Gymnodinium eurytopum **Skuja**	-	+	-	+	-	-	+	-	+
G. fuscum **(Ehr.) Stein**	+	+	-	-	-	-	-	-	-
Oxyrrhis marina **Dujardin**	-	-	+	-	+	+	-	-	-
Peridinium cinctum **(O.F. Mull.) Ehr.**	+	+	-	+	+	-	+	-	+
Woloszynskia leopoliensis **Thompson**	-	+	+	-	-	-	-	-	-
W. negleta **(Schilling) Thompson**	+	-	-	-	-	+	-	-	-

(-) = absent taxon; (+) = present taxon; (++) = abundant taxon (26-50%) ; (+++)= common taxon (51-75%)

S – Sanatorium sampling point ; B – Boathouse sampling point; T- Television tower sampling point

Table 2. Time (2004, 2007, 2009, 2010) and space (three sampling points) variability of phytoplankton structure in Lake Techirghiol

Structure of phytoplankton	Spatial variability	Temporal variability
Average number of species per sample	36	58
Number of species present in all sampling points	75	2
Number of samples containing all species	0	0
Margalef Index	7.23-7.79	4.54-11.03
Shannon Index	2.40-2.64	1.65-3.39

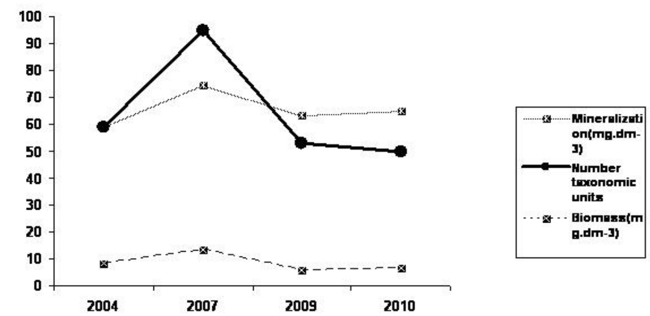

Figure 1. Relationship between structure of phytoplankton and mineralization of the lake Techirghiol

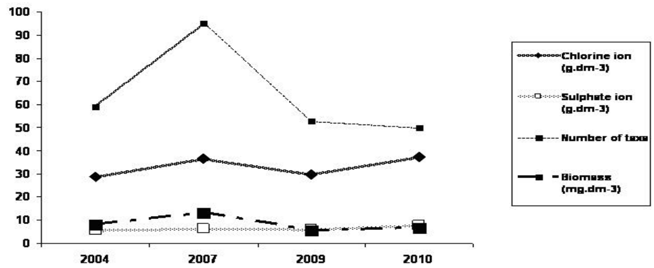

Figure 2. Variation of phytoplankton structure in lake Techirghiol depending on Cl- and SO42- concentrations (number of taxa, biomass)

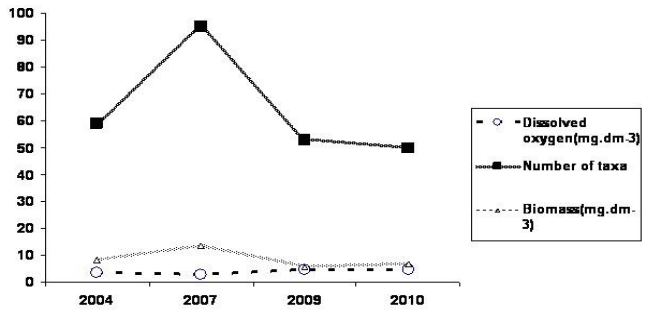

Figure 3. Variation of phytoplankton structure in lake Techirghiol depending on the dissolved oxygen (number of taxa, biomass)

Table 3. Numerical abundance percentage of phytoplankton taxa in Lake Techirghiol

Taxa	May 2004		June 2007		June 2009		June 2010		
	S	B	S	B	S	B	S	B	T
Euglenophyceae	2.29%	0.88%	2.09%	1.77%	0.28%	0.00%	0.00%	0.00%	1.04%
Bacillariophyceae	90.88%	48.28%	93.43%	95.13%	95.80%	98.12%	97.37%	98.35%	97.12%
Chlorophyceae	3.98%	8.74%	2.10%	1.58%	2.52%	0.93%	1.30%	1.65%	0.52%
Chrysophyceae	1.14%	0.00%	0.52%	0.23%	0.28%	0.19%	0.00%	0.00%	0.00%
Cryptophyceae	0.00%	0.00%	0.00%	0.23%	0.00%	0.19%	0.26%	0.00%	0.00%
Xantophyceae	0.00%	0.00%	0.27%	0.00%	0.00%	0.19%	0.00%	0.00%	0.00%
Dinophyceae	1.71%	5.23%	1.6%	1.12%	1.12%	0.38%	1.04%	0.00%	1.32%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00 %	100.00%	100.00%	100.00%

S - Sanatorium sampling point ; B - Boathouse sampling point; T - Television tower sampling point

Table 4. Dry biomass($g \bullet m^{-2}$) of the species *Cladophora crystallina* (Roth) Kütz

Distance from shore	Sanatorium June 2007														
	Transects 1/1					Transects 1/2					Transects 1/3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7.5 m	540	823.1	820.2	669.2	478.2	613.4	802.1	456.4	702.4	334.2	678.4	565.3	645.8	334.2	778.4
15 m	742.7	567.2	965.2	778.2	468.6	312.1	545.2	789.3	376.9	763.9	873.2	878.3	489.2	678.9	367.5
22.5 m	426.9	647.2	552.1	832.9	582.1	577.5	387.9	396.2	531.8	584.3	484.1	484.1	614.7	476.4	594.7
30 m	317.4	330	432.1	328.1	301.6	341.2	367.3	449.6	256.4	252.7	524.6	224.6	164.9	587.4	284.5
Average	506.7	591.9	692.4	652.1	457.6	461.1	525.6	522.9	466.9	483.8	640.1	538.1	478.6	519.2	506.3
Distance from shore	**Boathouse June 2009**														
	Transects 1/1					Transects 1/2					Transects 1/3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7.5 m	367.4	389.4	424.5	334.7	556.2	467.9	642.8	285.2	445.7	461.8	556.9	641.2	423.1	478.9	167.3
15 m	456.3	256.3	412.6	389.3	184.9	456.9	293.5	676.4	579.3	223.1	117.4	289.3	165.2	445.6	189.7
22.5 m	189.3	229.4	256.2	474.2	371.1	443.8	467.2	332.1	233.6	541.4	367.9	373.2	273.2	124.2	245.7
30 m	167.3	187.4	131.9	94.6	45.8	188.3	161.1	412.9	352.7	88.1	152.7	465.6	343.7	112.5	117.8
Average	295.1	265.6	306.3	323.2	289.5	389.2	391.2	426.6	402.8	328.6	298.7	440.1	301.3	290.3	180.1

Table 5. Physico-chemical parameters of water from lake Techirghiol (mean ±S.D) (30-50 cm depth) (INRMFB analysis bulletins)

Parameter	Sampling station		
	S	B	T
pH	8.38(±0.16)	8.35 (±0.18)	8.14 (±0.06)
Cl^{-1} ($mg \cdot dm^{-3}$)	31172.52 (±3178.19)	33588.43 (±6148.84)	30768.77 (±3724.94)
N-NO_3^- ($mg \cdot dm^{-3}$)	6.7 (±2.01)	7.6 (±2.20)	8.76 (±1.12)
HCO_3^- ($mg \cdot dm^{-3}$)	668.03 (±15.72)	694.23 (±7.26)	658.32(±19.95)
SO_4^{2-} ($mg \cdot dm^{-3}$)	6548.45 (±963.85)	6723.52 (±947.20)	7867.8 (±243.45)
Na^{1+} ($mg \cdot dm^{-3}$)	20107.68 (±2097.11)	21598.48 (±2704.37)	20802.83 (±1042.13)
Ca^{2+} ($mg \cdot dm^{-3}$)	330.8 (±92.35)	356.05 (±99.71)	235.63 (±17.08)
Mg^{2+} ($mg \cdot dm^{-3}$)	2472.12 (±84.92)	2679.35 (±19.07)	2498.87 (±)
N-NH_4^+ ($mg \cdot dm^{-3}$)	1.8 (±0.35)	2.1 (±0.2)	B.L.D.
Dissolved O_2 ($mg \cdot dm^{-3}$)	3.65 (±1.11)	3.9 (±0.56)	5.2 (±0.56)
Mineralization ($mg \cdot dm^{-3}$)	62.66 (±5.32)	67 (±8.14)	70.95 (±7.55)

S - Sanatorium sampling point ; B - Boathouse sampling point; T - Television tower sampling point

B.L.D. - below the limit of analitycal detection

Table 6. Density and biomass variability of phytoplakton groups in lake Techirghiol in 2004, 2007, 2009, 2010 (means)

	2004		2007		2009		2010	
	Density ($cell \cdot dm^{-3}$)	**Biomass w.s. ($mg \cdot dm^{-3}$)**	**Density ($cell \cdot dm^{-3}$)**	**Biomass w.s. ($mg \cdot dm^{-3}$)**	**Density ($cell \cdot dm^{-3}$)**	**Biomass w.s. ($mg \cdot dm^{-3}$)**	**Density ($cell \cdot dm^{-3}$)**	**Biomass w.s. ($mg \cdot dm^{-3}$)**
Euglenophyceae	$2 \cdot 10^3$	0.02	$6.5 \cdot 10^3$	0.8	$2 \cdot 10^3$	0.08	absent	absent
Bacillariophyceae	$2.45 \cdot 10^5$	6.8	$1.89 \cdot 10^6$	10.4	$7.88 \cdot 10^4$	4.7	$9.14 \cdot 10^3$	5.7
Chlorophyceae	$1.7 \cdot 10^4$	1.3	$1.1 \cdot 10^4$	1.8	$3.7 \cdot 10^3$	0.88	$6.3 \cdot 10^3$	1.2
Chrysophyceae	$2 \cdot 10^3$	0.17	$3 \cdot 10^3$	0.34	$2 \cdot 10^3$	0.09	absent	absent
Cryptophyceae	absent	absent	$3 \cdot 10^3$	0.02	$3 \cdot 10^3$	0.01	$2 \cdot 10^3$	0.008
Xantophyceae	absent	absent	$2 \cdot 10^3$	0.006	$2 \cdot 10^3$	0.002	absent	absent
Dinophyceae	$1.3 \cdot 10^3$	0.03	$5.7 \cdot 10^3$	0.08	$3.7 \cdot 10^3$	0.02	$1.1 \cdot 10^3$	0.01
Total	$2.79 \cdot 10^5$	8.32	$1.9212 \cdot 10^6$	13.446	$9.52 \cdot 10^4$	5.782	$1.854 \cdot 10^4$	6.918

w.s.= wet substance

Table 7. Microbiological indicators of pollution levels in Techirghiol lake (30-50 cm depth)

Pollution indicator bacteria	**May 2004**		**June 2007**		**June 2009**		**June 2010**		
	S	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**T**
Mesophilic aerobic bacteria to 37°C	>100 CFU / cm^3	>100 CFU / cm^3	>100 CFU/ cm^3	>100 CFU/ cm^3	>100 CFU / cm^3	>100 CFU / cm^3	65 CFU / cm^3	23 CFU / cm^3	15 CFU/ cm^3
Coliform bacteria	>100 CFU /100 cm^3	47 CFU /100 cm^3	>100 CFU /100 cm^3	>100 CFU /100 cm^3	109 CFU /100 cm^3	>100 CFU /100 cm^3	121 CFU /100 cm^3	69 CFU /100 cm^3	>100 CFU /100 cm^3
Escherichia coli	172 CFU /100 cm^3	47 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3
Intestinal enterococci	20 CFU /100 cm^3	12 CFU /100 cm^3	2 CFU /100 cm^3	2 CFU /100 cm^3	0 CFU /100 cm^3	2 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3	0 CFU /100 cm^3

CFU - colony forming units; S - Sanatorium sampling point ; B - Boathouse sampling point; T - Television tower sampling point

In descending order, come the green algae (Chlorophyceae), which have contributed with only 18.28% to the total specific diversity (recording a maximum of 22.03% in the year 2004, intermediate values in the years 2009 (20.75%), 2010 (22.00%), and a minimum of 12.63% in June 2007), and classes Dinophyceae (7.39%), Euglenophyceae (3.50%), Chrysohyceae (2.33%), Cryptophyceae (1.16%) and Xantophyceae (0.78%).
The values of the Margalef index indicate a variability of the phytoplanktonic density, more pronounced in time then in space, and the diversity of the species from the phytoplankton identified through the Shannon index, varied also less from one sampling point to another and more from a year to another.
The composition of the phytoplankton from lake Techirghiol has modified in time. If in the year 1954, I. Ţuculescu appreciated that in the plankton of lake Techirghiol, from the microphytes, the most numerous are the Bacillariophyceae, followed by the Cyanobacteria group and other unicelllular algae, and in the year 1977 the highest density was manifested by Bacillariophyceae and Euglenophyceae classes followed in descending order by Cyanobacteria and algae from the Chlorophyceae class (Trică 1977), the study which we realised between the years 2004-2010 reflects another structure of the phytoplankton from lake Techirghiol; numeric dominants in the microalgae group have been the diatoms, but those that follow in numeric abundance have been the Clorophyceae, Euglenophyceae (in the years 2004, 2007), Dinophyceae (2009), and Cryptophyceae (2010) (see Table 6).
For the phytoplanktonic biomass from lake Techirghiol, bibliography data show increased values in the period 1976-1978; from the year 1978, microalgae had a reduced biomass contribution to the sapropelic mud formation, until the year 1981. Starting with the year 1987, the phytoplanktonic biomass has registered a new rising tendency, but never have they reached the phytoplanktonic biomass values calculated in 1953 by I. Ţuculescu (see in 1965).
Not even the phytoplanktonic biomass values determinated in the years 2004, 2007, 2009 and 2010 haven't reached the ones from 1953 (Ţuculescu 1965); the most important biomass contribution the phytoplankton has registered in the year 2007 (13.4 w.s.($mg \cdot dm^{-3}$)) when even its numeric abundance was maximum, and the lowest was in 2009 (5.8 w.s.($mg \cdot dm^{-3}$)).

The effect of the water quality of the structure of the phytoplankton

The results registered during the study period reveal the tendency to associate the decrease of the mineralization values of the lake water (medium values for three sampling points in the years 2004, 2007, 2009, and 2010), with an increase of the number of taxa identified in the phytoplankton.

The biomass values of these microalgae have a proportional variation with the ones of the water mineralization; the highest quantity of organic substance was present in the phytoplankton in the year 2007, when even the mineral content of the lake water was maximum for the entire study interval (see Figure 1).
The high concentrations of the Cl^- and SO_4^{2-} ions have been associated with a large number of species in the phytoplankton and superior values of the microalgae biomass only in the year 2007; in 2004 the minimum concentration of these ions correspond with intermediate values of the number of taxa and phytoplankton biomass, and in 2009 and 2010 the concentrations of the main anions and the structure of the phytoplankton varied chaotic (see Figure 2).
The report of the cations $Na^+ > Mg^{2+} > Ca^{2+}$, was generally for any sampling point, during the realizing of the study; it created optimum conditions for the development of the phytoplankton, and especially, the calciphilic alga *Cladophora crystallina* (Roth) Kütz, that supplied an important quantity of biomass to the peloidogenesis process in 2007. For this species, the nitrogen compounds are often quoted as being limited nutrients (Dodds & Gudder 1992).
The concentration of the nitrogen compounds ($N\text{-}NH_4^+$,$N\text{-}NO_3^-$), have been sufficient for the insurance of the nutritional necessities of the phytoplankton, especially for the diatoms that have registered the highest diversity and biomass from the microalgae (see Table 6).
The oxygen concentration from the epilimnion varied independently from the number of taxonomic unities and the biomass value from the phytoplankton in the years 2004, 2007, 2009 and 2010 (see Figure 3).
The values of the oxygen saturation from the lake water (medium values) under 50% from 2004 and 2007 indicate a certain level of pollution, the results of the microbiological analysis reflecting this fact (see Table 7). In 2009 and 2010, Techirghiol ecosystem has been characterized by the superior self-purification capacity, according to the oxygen saturation of the water above 50%.

Conclusions

The number of taxa identified in the phytoplankton varied inverse proportionally with the mineralization level of the water, unlike the values of the phytoplanktonic biomass, that increased along with the water salinity.
The increased concentrations of the Cl^- and SO_4^{2-} ions have been associated with a diverse phytoplankton and with superior values of the microalgae biomass only for the year 2007.
The report of the $Na^+ > Mg^{2+} > Ca^{2+}$ cations, generally valid for any sampling point, has created optimal conditions for the development of the phytoplankton, and especially the calciphilic alga *Cladophora crystallina* (Roth) Kütz.
The concentrations of the nitrogen compounds ($N\text{-}NH_4^+$,$N\text{-}NO_3^-$) have been sufficient for the insurance of the nutritional necessities of the phytoplankton, especially for the diatoms that have registered the highest diversity and the highest biomass from the microalgae.
The 2004-2010 interval is characterised by a modification of the taxonomic structure of the phytoplankton of lake Techirghiol. Numeric dominant in the plankton was still the diatoms group, as in the precedent studies, but those that follow this time are the Clorophyceae, Euglenophyceae (in the years 2004, 2007), Dinophyceae (2009) and Cryptophyceae (2010).
The phytoplanktonic biomass was maximum in the year 2007; this maximum value is close to the one obtained in the years 1976-1978 (Trică 1977), but never has there been reached the phytoplanktonic biomass values calculated in the year 1953 by I. Ţuculescu.

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