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WATER TEMPERATURE VARIATION IN THE SALTY LAKES IN PRAHOVA'S SUBCARPATHIANS

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Abstract

Water temperature variation of the salty lakes of Telega and Doftana is influenced by meteorological parameters (air temperature, precipitation, air humidity, wind speed and cloudiness), the long and short wave radiation fluxes received / sent (they are influenced by the relative position of the sun in celestial vault at sunrise, noon and sunset), water salinity and waters' distribution on vertical, as well as lakes' mode of exploitation. Measurements carried out between May and November 2011 stressed the existence of some significant changes of temperature's distribution on vertical, instead of the data existing during the previous time period in literature (1964 - 2011), the most important being recorded in Doftana lake, due to the considerable decrease of the salty water horizon. During the hot season, when therapeutic bath processes are intensive in Dulce - Telega lake, up to a 3.3 m depth, temperature is uniform, while in Stavrică - Telega lake there is a direct thermal stratification. In November, when the therapeutic bath processes are over, the helio-thermal phenomenon reappears in Dulcea lake, while in Doftana and Stavrică lakes there is a uniform stratification, specific to autumn season.

Keywords: salt lakes, Doftana, Dulcea, Stavrică, water temperature

1. INTRODUCTION

Owing to their balneary potential, salty lakes in Prahova's Subcarpathians have been studied beginning from the second half of the last century (Gâştescu & Driga, 1969; Pişota & colab., 1969), most of the studies aiming at determining the main physical-chemical characteristics (temperature, transparency, color, salinity/mineralization), in relation to their forming mode and geometry measurement characteristics. The lakes' thermal balance is mainly influenced by four meteorological parameters: air temperature, air humidity, wind speed and cloudiness (Hostetler & Small 1999; Arhonditsis et all 2004; Kettle et all, 2004), besides the long and short wave radiation fluxes, received from Sun or sent by lake, during the daytime. Water temperature distribution tends to follow air temperature variability but, depending on lake's geometry measurement characteristics (lake's volume, maximum depth, lake's plan form, lake's length, lake's surface subjected to wind blow etc.) and radiant heat changes (positive or negative caloric balance) significant changes may appear. Water temperature distribution, at surface and on vertical, is influenced by the current climatic changes, and the lake responds to those (Dingman 1972; Edinger et. all., 1968; DeStasio et all, 1996; Livingstone, D. M. 2003) - it represents a necessity for being able to make predictions on the lakes' thermal behavior (Mazumder&Taylor1994; Livingstone & Dokulil, 2001). Unfortunately, the absence of previous records of water temperature makes hard to compare the current values and to establish some evolutional benchmarks, for, at least, the previous 10 - 20 years, the only available information on the analyzed lakes' thermal science is from 1964 – Pişota & colab. (1969) and 1967/1968 – Gâştescu & Driga (1969). The lakes of Telega lie on the left bank of the Mislea brook (Dulce, Stavrică, Baia Centrală and Palada lakes – today developed and named as Şoimul complex), on the left bank of the Doftana river, respectively, for the same-named lake. Salt exploitation for Telega area has been mentioned beginning from the second half of the XVI-th century (1562) (Toma & colab, 2008) and worked up to the second half of the XIX-th century, in 1872 (Meruţiu, 1912 cited by Pişota & colab, 1969) when, gradually, the once abandoned salt mines were flooded. The analyzed lakes within the present study have an underground intake, very small, or almost inexistent drainage areas, small surfaces (table 1), high depths and salinity significant variations on vertical, which influences distribution of water temperature on vertical.

Table 1. Geometry measurement elements of the salty lakes in Prahova's Subcarpaţi

Name	Altitude	Surface	Volume (m^3)	Maximum Depth (m)
Doftana	413	10673	63342	20
Dulce	424	1480*	13380*	14.5
Stavrică	415	1740*	48918*	100*

*(after Pişota & colab., 1969)

2. METHODS

The present study aims at analyzing distribution of water temperature, on vertical, in Doftana, Dulce and Stavrică lakes, based on the measurements done during expedition between May and November 2011 (monthly, or even twice per month). There was used multi-parameter equipment for determination of water temperature variation on vertical, salinity, pH, dissolved oxygen and saturation-in-oxygen, water conductivity, TDS, for transparency measurement, also the 30 cm in diameter Secchi disk was used. The lakes selected in the present study lie very close to each other (Stavrică and Dulce lie at 100 m distance from each other, and Doftana lies at 1 km away from the first two), being subjected to the same climatic conditions, and salinity is very close, beginning from the depth of 14 m, but the exploitation mode is different: Dulce lake is intensely used in therapeutic bath processes during the hot season; Stavrica lake is not used for therapeutic bath; Doftana lake has significantly reduced salinity in the 1-8 m horizon, to only 1 gr./l.

3. RESULT AND DISCUSSION

Water salinity, conductivity, respectively, with very high values (fig. 1) (Williams & Sherwood 1994; Anati, 1999) directly influence the phenomenon which is the most associated to those lakes, known as „helio-thermal phenomenon"- development of a warmer water lens, due to absorption of solar radiation (Sonnenfeld & Hudec 1980, p. 93, Alexe 2010). The solar origin of this heating was indicated by Ziegler (1898), and was demonstrated by measurements made by Kalecsinszky (1901). The further measurements made by Maxim (1929, 1931, 1937, 1943), in the anthropo-saline lakes in Transylvania have confirmed the phenomenon and, for the first time the name of „***helio-thermal phenomenon***" was introduced (Sonnenfeld & Hudec 1980). The foreign literature indicates a small number of studies on that phenomenon, many times being associated with some species' accommodation at the temperature conditions and with their thermal-regulator role, while in Romania there is a high number of studies on that phenomenon, being mainly studied in the lakes in Transylvania Depression, but also in those of Slănic Prahova and Telega (Maxim 1929, 1931, 1937, 1942, 1943-1944; Sturza 1950; Patriciu 1962; Gâştescu 1963, 1971; Gâştescu & colab. 1969, 1985, 1993; Panait & Bobeică 1967, 1968; Pânzaru 1969, 1970, 1971, 1974, 1975, 1976, 1982, Pişota & Trufaş 1969, 1971; Bulgăreanu 1976, 1978, 1981, 1983 etc.). In the salty lakes, where there is a horizon at surface, having a more reduced salinity (20-60 gr/l), a mezzo-thermal phenomenon is produced – increase of temperature in metalimnion – here temperatures being higher by up to 10 - 15°C, compared to surface, while in hypolimnion, temperatures are generally between 12 and 14°C (Gâştescu & colab. 1993), which values are also confirmed by our measurements (fig. 2). The absence of salinity differences, due to the lack of precipitation or to intakes from surface sources, in combination with a high evaporation, leads to a continuous decrease of the surface temperature, up to a depth of abt. 14 m (fig. 2), and to the disappearance phenomenon, as it was found out in Stavrică lake, in July / August 2011.

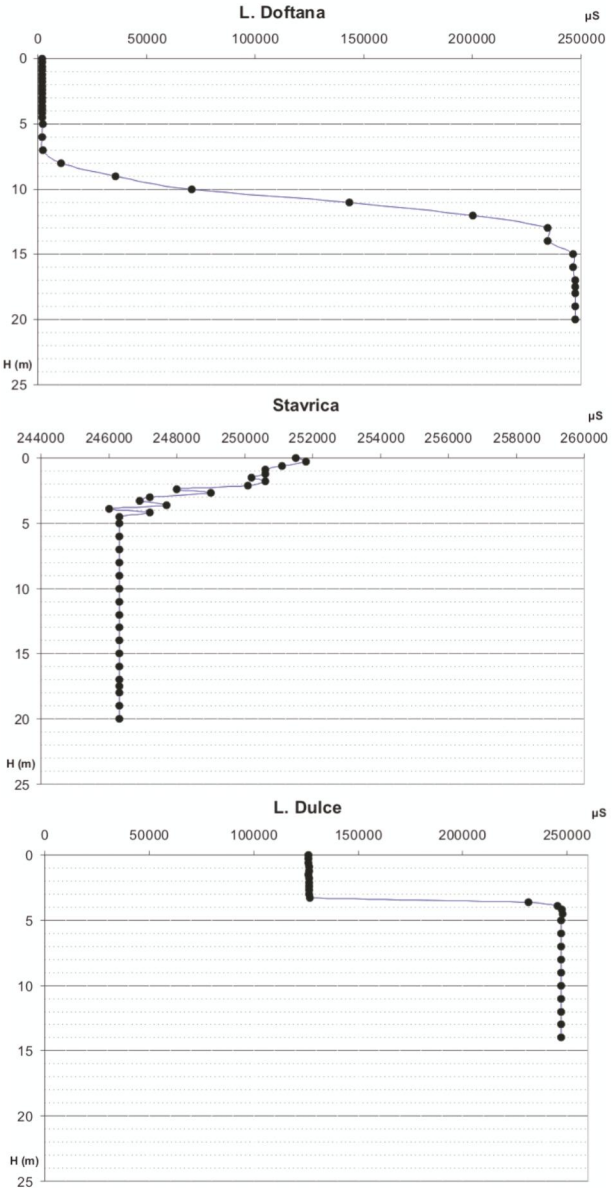

Fig. 1. Water conductivity of Doftana, Stavrică, Dulce lakes – 07.28.2012 (µS)

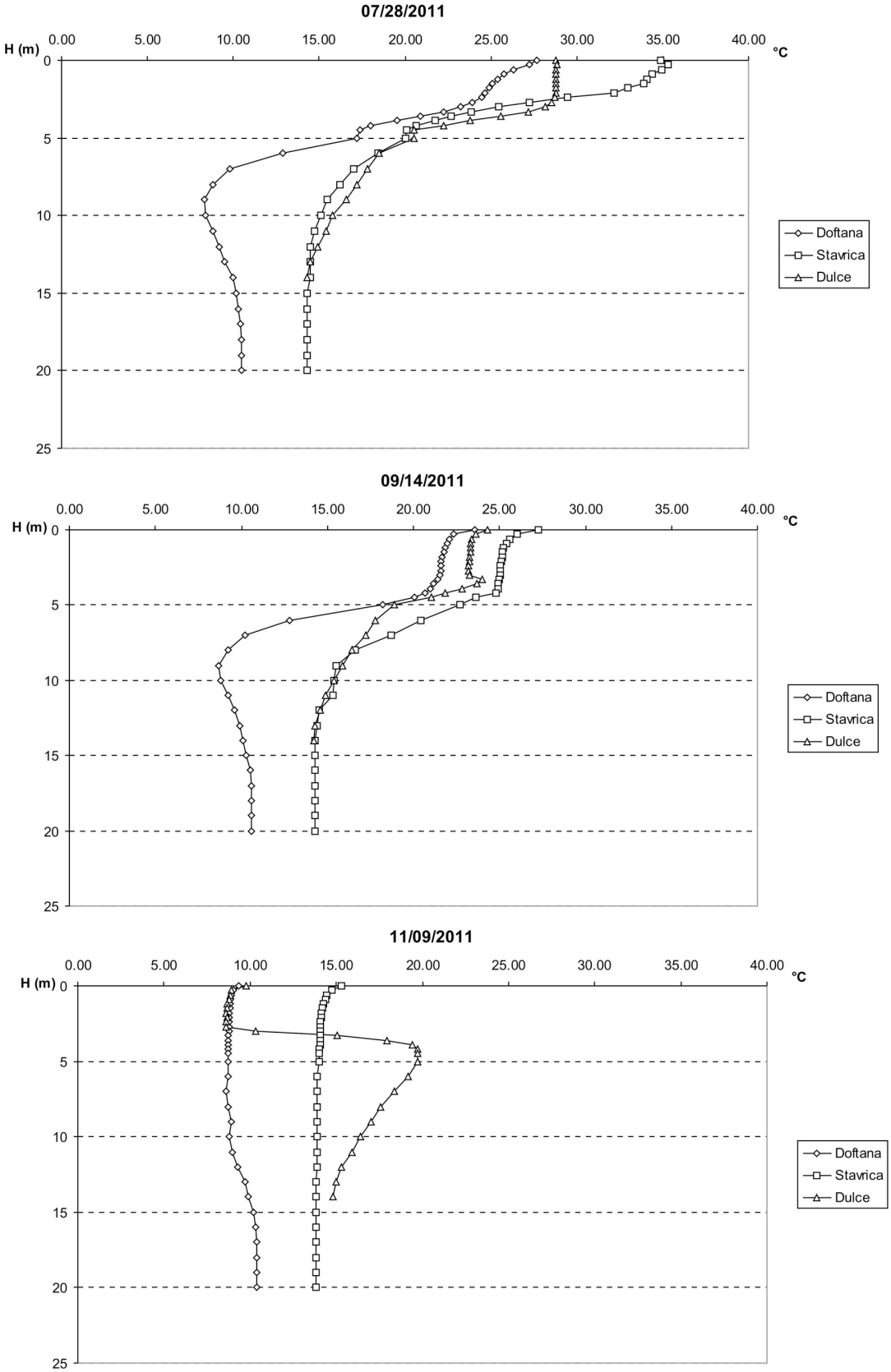

Fig. 2. Distribution of water temperature on vertical, in Doftana, Stavrică, Dulce lakes, in June, September, November 2011

In case of Doftana lake, the change of hydro-chemical and of geometry measurement characteristics has determined disappearance of helio-thermal phenomenon, which existed in the past in the lake (fig. 5), as well as temperature decrease in the lower horizon. Thus, the measurements done in 1964 (Pisota&colab,

1969) and between 1967 and 1968 (Gastescu&Driga, 1969) stressed relatively constant values of water temperature in hypolimnion – of abt. 14°C (values found out in 2011, in lakes of Telega, beginning with the depth of 13 - 14 m), in summer of 2011, in Doftana lake, the temperature beginning from a depth of 14 m and up to 20 m is constant – 10.5°C. That phenomenon is due to the water layer with a low salinity, in the 0 - 8 m horizon (salinity is constant of abt. 1.20 – 1.25 gr/l), which does not receive enough caloric energy to transfer in lower horizons either (fig. 3).

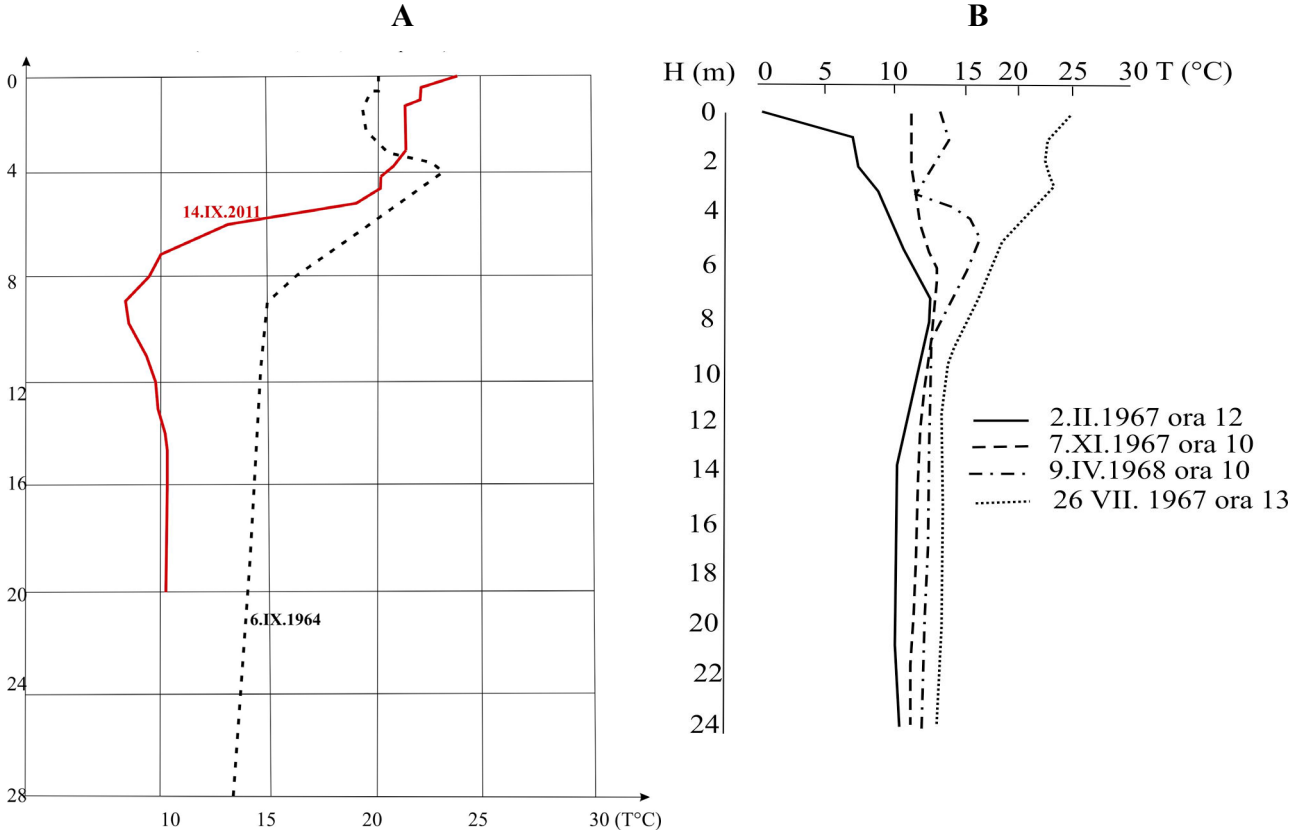

Fig. 3 Thermal vertical profile in Doftana lake, on 06.09.1964 (acc. to Pişota & colab., 1969), 14.09.2011 (A) and temperature evolution on vertical, in 1967 and 1968 (Gâştescu & Driga, 1969) (B)

For analyzing the thermal regime on vertical, three vertical profiles have been selected, which we may consider as representative for the analyzed time period, i.e. the ones in: July (high air temperatures, the highest water temperatures recorded during the observation period, respectively, intensive evaporation, intensive therapeutic bath processes), September (air temperature decrease, absence of therapeutic bath) and November 2011 (low air temperatures, lack of therapeutic bath), during that time precipitations being very low. Previously, in May and June, thermal stratification in all the three lakes was direct, with slightly higher temperatures at surface than those at a depth of 14 m (beginning from 14 m, water temperature was constant throughout the observation time period).

The temperatures measured by us during the campaigns in the summer of 2011 stressed the maximum values exceeding 35°C in Stavrică lake, while on the same day, water temperature in Doftana and Dulce lakes had maximum values of 27 to 29°C (fig. 2). The previous measurements done by Pişota & colab. (1969) in 1964 show the temperature of 35°C, as a maximum recorded value, in other lakes in Prahova's Subcarpați (Baia Verde II lake, on 07.06.1964), while values slightly exceeding 35°C were also recorded in Dulce lake, on 07.11.1964. After that time period, evolution of water temperature in metalimnion, in summer season, recorded a decrease of values, which phenomenon is explained by the heat losses due to therapeutic bath (Dulce lake), but it could have as cause, a decrease of salinity differences in epilimnion, due to intensive evaporation (Stavrică lake). The measurements done in Stavrică lake, in November 2011, stressed an almost perfect uniformity of temperatures, from depths of 0.3 m, up to 50 m, the values being between 14.73 and 13.8°C (fig. 4). In purposes of comparison, in the same lake, in December 2010, temperature in metalimnion in the 2 - 5 m horizon reached 18°C, and from 14 m depth it kept constant of 14.3°C. We found again that water temperature value of 14.3°C, at that depth, throughout the measurements in summer and autumn of 2011, under the conditions where precipitations were decreased, and water conductivity was relatively constant, having very high values, on the entire vertical.

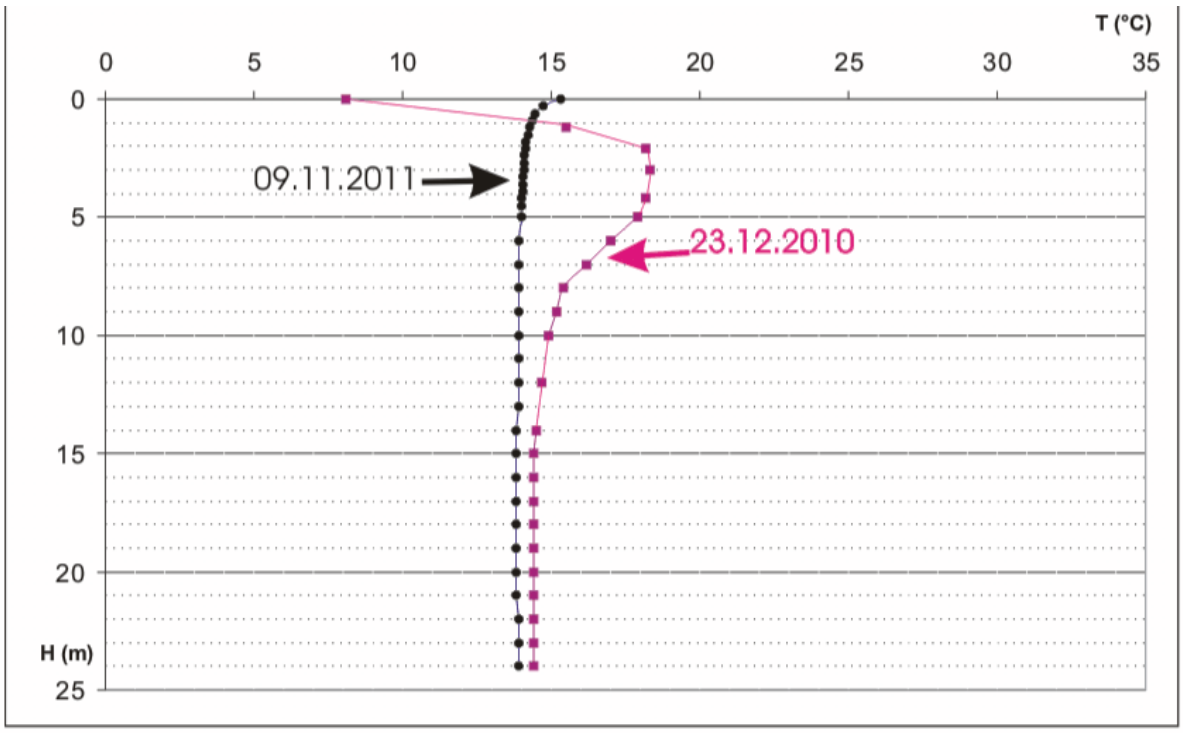

Fig. 4 Temperature distribution on vertical, in November 2011 and December 2010, in Stavrică lake

Nevertheless, therapeutic bath is very important, especially in small lakes, without intake superficial sources, as beside temperature uniformity up to a 3 m depth, also the heat amount is reduced, heat which can be absorbed and stored by lake, due to turbidity increase and transparency decrease (in Dulce lake, in the summer season, transparency had values of 0.5 m at noon). The measurements done in Doftana lake, between May and September 2011, stressed very good correlations between air and water temperature increase, from surface up to a depth of 8 -10 m. Though there is an important number of measurements, on water temperature in salty lakes in metalimnion, in absence of some measurements, systematically or, at least annually done, during the hot season (but with a starting base after ice bridge melting or spring beginning), we cannot draw pertinent conclusions on appearance, evolution or „disappearance" of the helio-thermal/mezzo-thermal phenomenon.

6. CONCLUSIONS

Water temperature distribution analysis on vertical, of Doftana, Stavrică and Dulce lakes, based on the measurements done between May and November 2011, stressed the existence of some significant changes besides the data existing during the previous time period in literature (1964-2011), which changes are caused by the temperature/evaporation/precipitation/salinity relations, as well as by the lakes' exploitation mode.

Further we mention a few of the most important changes, noticed by us, up to now:

- water temperature from the depth of 14 m keeps constant, up to the lake's bottom, of abt. 14°C (Stavrică and Dulce lakes), except Doftana lake, where we found out the value of 10.5°C (in the past, measurements showed also values of 14°C)
- evolution of water temperature, on vertical, in Doftana lake, has been changed under-layer, due to the decrease of the salty water horizon
- in Dulce lake, due to the intensive usage, by tourists, water transparency is reduced (0.5 m), and up to the depth of 3.3 m, the temperature is uniform
- absence of salinity differences, of a horizon with a reduced salinity at surface, respectively, made temperature be uniform up to the depth of 50 m in Stavrica lake, in November 2011, (in December 2010, measurements stressed by the helio-thermal phenomenon, due to a rainy weather, which allowed accumulation of a less salty horizon at surface).

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