

DIYADIN (AGRI REGION, TURKEY) - A POORLY KNOWN THERMAL ECOSYSTEM

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Abstract. The thermal water ecosystem of Diyadin (Agri region) is poorly known in terms of biodiversity, as only few bacteria species were identified and some of their specific enzymes were isolated. However, the geological structure of this old inactive volcanic zone as well as the chemical composition of the thermal water characterized by therapeutic properties and temperatures up to 64°C were thoroughly studied. Diyadin zone has been insufficiently capitalized from the tourist and industrial viewpoints so far, but the discovery of some gold deposits seems to revitalize its economy. The present paper is the first one dedicated to the ciliates living in surface thermal waters; 9 species have been identified till present. The data are preliminary and they will be completed with other data after the inventory of other protozoa and metazoa species, which could represent new taxa or varieties of the species originating in the Murat River and adapted to the special abiotical factors of this ecosystem.

Keywords: Diyadin, ciliates, gold deposit, tourism potential.

Rezumat. Diyadin (Regiunea Agri, Turcia) – un ecosistem termal puțin cunoscut. Ecosistemul apelor termale de la Diyadin (zona Agri, Turcia) este puțin cunoscut din punctul de vedere al biodiversității, fiind identificate câteva specii de bacterii și izolate enzime specifice ale acestora; în compensație însă, structura geologică a acestei zone vulcanice inactive a fost relativ bine studiată ca și compoziția chimică a apelor cu proprietăți terapeutice și temperaturi de până la 64°C. Zona, insuficient pusă în valoare din punct de vedere turistic și industrial, prezintă mai nou interes economic deosebit prin descoperirea unor zăcăminte aurifere. Lucrarea de față este prima dedicată ciliatelor din sedimentele apelor termale de la suprafață, fiind identificate primele nouă forme; datele sunt preliminare urmând a fi completate după inventarierea altor specii de protozoare și metazoare care pot reprezenta specii noi pentru știință sau varietăți ale unor specii posibil provenite din Râul Murat și adaptate la factorii abiotici speciali ai ecosistemului.

Cuvinte cheie: Diyadin, ciliate, depozit aurifer, potențial turistic.

INTRODUCTION

Diyadin (Kürtçe: Giyadîn) is a district situated in the eastern part of Turkey (geographical province Dogu Anadolu, (Fig. 1 – Map; Figs. 2-3a, b, c) in Agri region, only 7 kilometres from the town with the same name. Situated at an altitude of 1,925 metres, it registered a total population of 45,395 inhabitants in 2013, which means 26,735 inhabitants more than in 1965, when the first official population census was made (Wikipedia, 2013; 2015).

Despite the reduced number of inhabitants, Diyadin started to present interest since 1998 due to its location within an area with thermal waters; for us, the area is very important as it represents the place where the Murat River springs from and it has interesting ecosystems.

We have not found many papers regarding the ecosystem of the thermal waters from Diyadin; however, there were made some well-documented research studies about the geological structure of the area and the chemical composition of thermal waters (ZAMAN et al., 1999; PASVANOGLU, 2013), as well as about some bacteria species and the isolation of certain enzymes specific to their composition (BELDUZ et al., 2003; SANDALLI et al., 2008; BEKLER et al., 2014). As there have not been found any information regarding the protozoa and metazoa biodiversity in Diyadin area, we consider that our paper is original.

Geo-chemical characteristics.

The city is located within a former volcanic area; the history of the formation of these complex geological structures is ancient, because Turkey is located along the Alpine Himalayan orogenic belt that formed parts of the Tethys Ocean with grabens, faults, volcanoes and hydrothermal alteration zones that control its geothermal activity. The continental crust of Turkey was broken up as the Anatolian subplate in Pliocene and has been displaced northwards since Oligo-Miocene by the movement of the Arabian plate. The fragmentation allowed **lava** intrusion in Eastern Anatolia and resulted in extensive volcanic activity and the formation of several stratovolcanoes including Agri (Diyadin is situated in Agri region n.a.).

Diyadin geothermal area is located in a zone which is extensively affected by neotectonic movements. Several strike – slip faults and tensional fractures developed in association with N-S regional compression.

The Diyadin lava is 20-30 m thick and is exposed along the Murat River. From the fissures of the volcanic lava, there emerge thermal waters with temperatures varying between 30 and 64°C and a flow between 0.5 and 10 l/s (PASVANOGLU, 2013).

The interest to study the region increased especially after 1999, when a team of geography professors from Atatürk University of Erzurum started their researches revealing the first geological and chemical information.

The aforementioned work is remarkable due to the excellent maps of Diyadin area, rigorous description of the geological substrate (result of the drillings) and complex tables about the chemical composition of the thermal water (ZAMAN et al., 1999).

As a result of the scientific investigation, there were established four important categories of thermal waters; three of them come from a depth between 2,049 to 1,946 meters, present a pH between 6.26 and 7.90 and temperatures values from 30 to 76°C. The fourth - category is a cold stream coming from 1,925 meters deep, rich in HCO^{-3} , Ca^{2+} and Mg^{2+} .

The thermal waters contain many chemical elements, but the highest concentrations - are registered by Ca^{2+} (over 762 mg/L) and HCO^{-3} over 2,013 mg/L. The gas composition of the thermal springs-is mainly represented by CO_2 , but, there are also present CH_4 , O_2N_2 , C_2H_6 and H_2S in smaller concentrations (PASVANOGLU, 2013).

A recent study emphasized the presence of gold into the sediments from the region; the concentration of gold into the 699 analysed samples varied between 0.005 and 10.1 ppm (COLAKOGLU et al., 2011).

DIYADIN – REGION WITH INDUSTRIAL AND TURISTIC POTENTIAL

As a result of different researches regarding the chemical composition of Diyadin thermal waters and also due to the touristic potential of the region – represented by natural landscapes less affected by anthropogenic influences - in 1998, the works for the thermal water catchment started.

In 1996, there were built the first open pools with thermal water for tourists using the water brought through pipes from a depth of 25 meters (ZAMAN et al., 1999). Unfortunately, there were not made further investments to extend the pools or to modernize them (Figs. 5; 6).

Today, the touristic investments in Diyadin thermal region are poor, only six hotels (two and three stars) each of them having an accommodation capacity between 25 and 120 rooms. The reasons for the lack of serious investments such as five stars hotels could be the poor infrastructure from the main road to Diyadin and present state of the pools (they are old and need modernization), etc. (Figs. 5; 6) (Dyadinnet 2015).

The year 1998 marked the start of the activity of intensive geothermal exploitation of the region; the drillings were coordinated by MTA (Directorate of Mineral research and Exploitation of Turkey); six drilling were made in order to bring thermal water from 215 meters deep at a flow of 420 litre/sec.; today, only one source is functional transporting the thermal water to the users through a 7 km long pipeline; the temperature of the water delivered to the users is 60°C.

In the same year, ten greenhouses were finished (30 meter length, 10 meter width); there was used the thermal water from cold source, brought by the pumping system (Diyadin Jeotermal, 2015).

In 2001, it was built a factory for manufacturing liquefied CO_2 and dry ice, having a daily production of 100 tons, by a common Turkish-German investment (PASVANOGLU, 2013).

MATERIAL AND METHODS

The first phase consisted in a serious documentation study of the scientific papers dedicated to Diyadin thermal ecosystem; then, it followed a field trip to the pools. Water is brought through pipes to the pools, which were built in 1996, from the big spring situated 25 meters away; water is permanently discharged from the pools (see the original photos).

During the field trips from May 2014, 30 water and sediment samples were collected from the superficial zone situated near the big thermal water spring (Figs. 2-6). The present data are preliminary; they will be completed by other results obtained after studying the species of ciliates in detail, taking samples from different depths, the pools and the discharge zone; establishing the complete list of metazoa and protozoa species living into sediments, etc.

The study of the ciliates from sediments is made using the same classical methods - thoroughly described in other scientific papers (KERKMANN et al., 2012); the examination was very difficult (in vivo and using vital coloration) because they are active only at high temperatures (when samples were taken, the average temperature was of about 45 °C). A temperature increase has as consequence a rapid transition of the species from the active to the cyst stage. For this reason, the samples were maintained at a constant temperature during the examination with a hot plate (Fig. 7).

RESULTS AND DISCUSSIONS

Till now, in the sediments of thermal waters from Diyadin, 9 ciliate forms were identified, 6 of them only to gender. Three of the species are found on the list proposed by Kermann for the Murat River (Agri region) (KERKMANN, 2014). The rest of the species must be very carefully examined in the future using DNA extraction techniques in combination with argentic impregnation (DRAGESCO & DRAGESCO-KERNEIS, 1986); they could be either new species or varieties of common cosmopolite species, having eurytherme valences. There follows a short description of these species and their ecological characterization.

Colpoda cucullus (Muller 1773) Gmelin 1790

The species was very abundant in the collected samples, their length ranging between 40 and 120 μm , complying with the limits quoted in the protistological literature (FOÏSSNER et al., 1991). The species has cosmopolite and eurytherme affinities (FOÏSSNER et al., 1991); their main food consists in bacteria, flagellates and small algae (FOÏSSNER & BERGER, 1996).

The saprobity degree of an ecosystem indicated by this species varies according to different scientists: thus, according to Detcheva's saprobic system (DETCHEVA, 1983 in: FOÏSSNER et al., 1991), *Colpoda ccullus* is oligo-beta-saprobic but in Foissner's system, the same species is poly-alpha mesosaprobic (FOÏSSNER & BERGER, 1996). The species

is eurytherme resisting to temperatures between 0 and 25°C; the identification of the present species in samples with much higher temperature values than those mentioned in the specialized literature may indicate a new variety of the same species with thermophilic affinities; further genetic and protistological studies will confirm this hypothesis.

Colpoda cucullus presents an increased tolerance to high concentrations of calcium and magnesium compounds (Ca^{2+} 12-65.7 mg/l; Mg^{2+} 6.1-15.6 mg/l), as well as to high concentrations of HCO_3^- ions (23.5-298.9 mg/l) (DETCHEVA, 1983 in: FOISSNER et al., 1991). The values of the calcium and magnesium ions registered in case of the Murat River (Diyadin area is directly connected to it), which are within the limits established for *Colpoda cucullus* (Ca^{2+} 44.2 mg/l, Mg^{2+} 10.4 mg/l) (PASVANOGLU, 2013, table 1, p. 71) lead us to the hypothesis of a possible migration of the species from the river towards the area of the thermal springs together with their adaptation to the abiotic factors specific to this ecosystem.

It belongs to the BOD saprobic community (FOISSNER & BERGER, 1996), which indicates the influence of the soil in this particular ecosystem, fact confirmed by the topography of the zone where the thermal facilities are located, including the discharge points that emerge on the superficial soil layer (Fig. 7).

***Colpoda steinii* Maupas 1883**

The length of the samples is between 10 and 60 μm (FOISSNER & BERGER, 1996) and the samples taken from the sediments from Diyadin area are within these limits. The species is found in water with pH between 4.8 and 5.0; it is eurytherme, 1.0-14.4°C, and tolerates the presence of hydrogen sulphide at concentrations between 0 and 0.5 mg/l (FOISSNER et al., 1991). The hypothesis of its migration from the Murat River and appearance of a variety is maintained for this species too. The species is cosmopolite (FOISSNER et al., 1991), bacterivore, indicator of alpha to polysaprobic zones and belongs to the BOD community (FOISSNER & BERGER, 1996) (Fig. 8).

***Oxytricha saprobia* Kahl 1932**

The samples identified in Diyadin ecosystem had an average length of 100 μm , being consistent with the data cited in protistological literature (FOISSNER et al., 1991, 291-293 pp.). The trophic base is represented by bacteria and flagellates. *Oxytricha saprobia* represents a bioindicator of alpha to polysaprobic zone (FOISSNER & BERGER, 1996). Another two species belonging to this were identified; the investigations to establish exactly the diagnosis of the species will be extended in the future.

***Urotricha* sp.**

The number of the specimens belonging to this species was abundant in the examined samples (their length 60-90 μm); the main food consists in bacteria, small algae and flagellates, but other species are predators. It indicates beta-mesosaprobic zones and according to Foissner and Berger it belongs to OLI saprobic community (Oligotrichetea) (FOISSNER & BERGER, 1996). It is an eurytherme species (0-25°C) and resists to variations of the pH between 6.8 and 8.2 (FOISSNER et al., 1991).

***Stylonychia* sp.**

The specimens of this species had low abundance in the samples collected from Diyadin; their length varies between 75 and 110 μm (the dates from the protistological literature are between 60 and 125 μm) (FOISSNER et al., 1991). They can resist to temperatures of more than 20°C (FOISSNER et al., 1991), but, according to other authors, temperature range is between 0 and 25°C (BICK, 1972). Their food diet is omnivore and they are indicators of alpha to polysaprobic zones (FOISSNER & BERGER, 1996) (Fig. 9).

***Aspidisca* sp.**

The specimens of this species (without notable abundance) had a maximum length of 50 μm , complying with data quoted in protistological books (BERGER et al., 1997, pp. 153-158). It is a cosmopolite species, indicating alpha to polysaprobic degree; its food diet consists in bacteria (FOISSNER & BERGER, 1996).

***Spathidium* sp.**

The abundant species of this genus present a length of 50-250 μm (DRAGESCO & DRAGESCO - KERNEIS, 1986). They are predators, belonging to BOD saprobic community (FOISSNER & BERGER, 1996). Only few specimens, with a length of 65-130 μm , were identified in our samples.

CONCLUSIONS

In the examined sediment samples (from the touristic zone) 9 ciliate forms were identified; they are cosmopolite, eurytherme and six of them were determined only to genus.

Most of the forms are evolved ciliates, having the mouth ciliature very well differentiated from the body ciliature and organized in complex structures; it is possible that this evolution degree induced their increased adaptative flexibility ensuring their survival in this ecosystem characterized by specific values of the abiotic factors. The most recent taxonomical classification of ciliates was extensively discussed in our last scientific paper about ciliates fauna of the Murat River (KERKMANN, 2014).

The presence of three ciliates species on the list proposed by Kerkmann for the Murat River (Agri region) (KERKMANN, 2014), as well as the close connection with the Murat River, which springs from Diyadin area, supports the hypothesis of new species or of certain common species but with thermophile varieties. To confirm this hypothesis, it is necessary to establish exactly the diagnosis through classical taxonomical methods (argentic impregnations) and isolation of DNA from ciliates cultures.

Diyadin zone presents an increased geothermal, aeolian and touristic potential, which has not been properly capitalized so far; from the biodiversity point of view, it is a vast research-field for all the eventually interested scientists.

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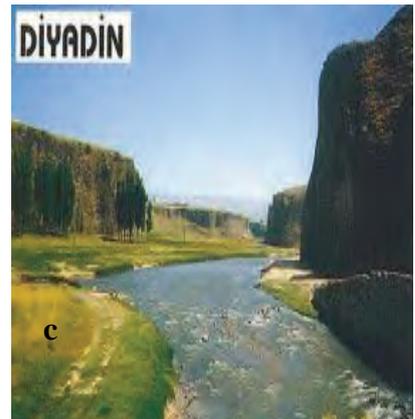
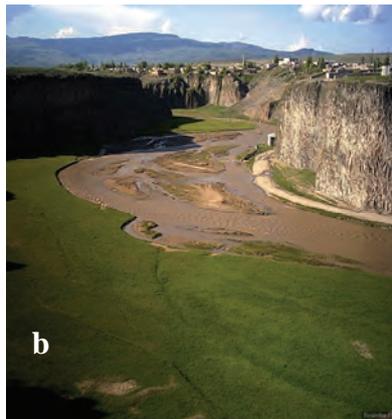
Figure 1. Map of Agri region (Wikipedia, 2015).



Figure 2. Diyardin landscape – volcanic rocks and thermal spring (original photo).



Figure 3a. Details of a thermal spring from Diyardin area (original photo).



Figures 3b, c. Diyardin landscape (19).



Figure 4. Thermal spring emerging at the surface (sulphur smell and very hot water) (original photo).



Figure 5. Swimming pool and the water pipe from the source (see photo 1 and 2) (original photos).



Figure 6. Samples containing water and sediments from Diyardin thermal springs (45°C) (original photo).



Figure 7. *Amoeba* sp.
(Diyadin, 35 μm length, original photo).

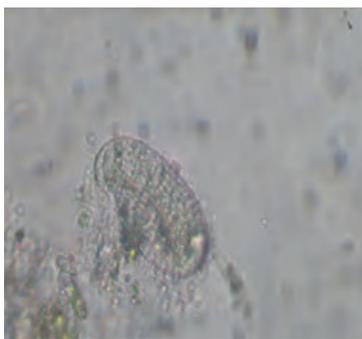


Figure 8. *Colpoda steinii*
(Diyadin, 55 μm length, original photo).

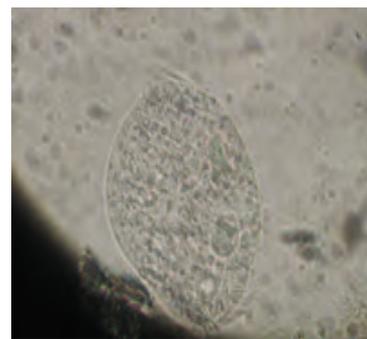


Figure 9. *Stylonychia* sp.
(Diyadin, 110 μm length, original photo).

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