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Algae Flora of Germencik-Alangüllü (Aydın, Turkey) Thermal Water

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Abstract

Our country is very rich in thermal water resources. In particular, the thermal waters of the Aegean Region are remarkable geothermal fields which has with different physicochemical parameters. There are studies in the literature of our country regarding thermal water algae flora. On the other hand, considering the multitude of thermal waters in our country this number is insufficient. This study has been done in order to make up this deficiency in the literature. Within the scope of the study, sampling was performed periodically for 12 months, and species composition have been determined. In this paper, a total of 27 taxa have been identified (21 Cyanobacteria, 5 Bacillariophyceae and 1 Conjugatophyceae). The thermal algae diversity which is distributed in the Germencik (Alangüllü) thermal water source has been tried to be determined.

Keywords — Algae, Flora, Germencik (Alangüllü) Thermal Water, Taxonomy, Turkey

1 Introduction

Turkey is very rich in thermal water resources. In particular, the thermal waters of the Aegean Region are remarkable geothermal fields which have with different physicochemical parameters. The number of living things spreading in the thermal water environment is rather low. Because of the many living species cannot tolerate high temperatures, the thermal waters are quite extreme habitats for living organisms. Also thermal waters are create a special living environment, with various substances dissolved in their constituents. It is noteworthy that our country's fauna and flora studies related to thermal waters are virtually absent in literature.

There are studies in the literature of our country regarding thermal water algae flora (Table 1). On the other hand, considering the multitude of thermal waters in our country, this number is insufficient. This study has been done in order to make up this deficiency in the literature.

Table 1. Studies on Turkish thermal water algae flora from the past to the present day.

Author(s)	Year of Publication	Subject of Publication
Regel and Skuja	[1]	Algae flora of Pamukkale
Güner	[2]	Microalgae flora of Pamukkale thermal water
Güner	[3]	Microalgae flora of Aegean region thermal water
Güner	[4]	Algae vegetation of Aegean region spa and mineral waters
Aysel et al.	[5]	Algae flora of Zonguldak Ilıksu thermal water
Ünal	[6]	Algae flora of Balçova thermal water
Ulcay et al.	[7]	Thermal algae flora of Manisa thermal water
Ulcay et al.	[8]	Thermal algae flora of Dikili thermal water
Çadırcı et al.	[9]	Thermophilic Cyanobacteria members Balçova thermal water
İçyüz et al.	[10]	Investigation of antimicrobial and antifungal activity of Pseudanabaena sp. isolated from Denizli Sarayköy thermal source
Yüksel et al.	[11]	Isolation and molecular identification of some thermophilic Cyanobacteria members.
Demirel and Sukatar	[12]	Cyanobacterial phycobiliproteins isolated from İzmir thermal water
Demirel et al.	[13]	Cyanobacterial toxins isolated from İzmir thermal water

Demirel and Sukatar	[14]	Molecular identification of Cyanobacteria members and their toxins isolated from İzmir thermal water
Ulcay et al.	[15]	Algae flora and other living organisms in Kaklik Cave and surrounding thermal waters
Ulcay et al.	[16]	Comparative analysis of Pamukkale thermal water microflora 45 years ago and today

2 Material and Method

The material of this study is algae flora that spread in the Germencik (Alangüllü) thermal water source which is located within the boundaries of Aydın province (37° 53' 11'' K, 27° 35' 27'' D). Within the scope of the study, sampling was performed periodically for 12 months in between 2013 and 2014, and species composition have been determined.

For the sampling, thermal water outlet areas and water pools were selected, and sampling was based on 3 different localities (Figure 1).

Figure 1. Germencik (Alangüllü) thermal water outlet points and sampling stations.

During the identifications of collected samples and the determination of taxa were made according to previous studies [7, 8, 17-23] and the data in the AlgaeBase and Cyanodb digital resources for Cyanobacteria members, [23, 24, 25] and the data in the AlgaeBase database for Bacillariophyceae and Conjugatophyceae members. Also taxonomic positions of both determined algae were made by the Komárek and Anagnostidis [22] for Cyanobacteria members and the AlgaeBase digital resource for Bacillariophyceae and Conjugatophyceae members.

Olympus BX50 camera and phase contrast microscope were used for the photographing of each assigned taxa. Also physicochemical parameters of the Germencik (Alangüllü) thermal water were measured by water quality meter (WQC 24), and given in Table 2 as mean values.

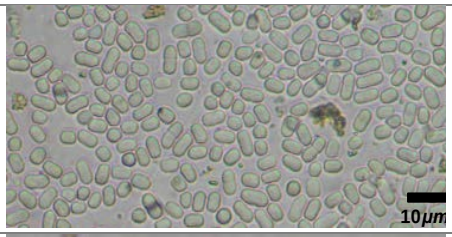
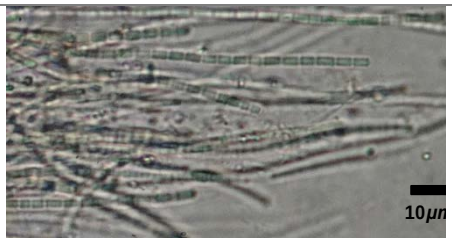
Table 2. Annual average physicochemical parameters of Germencik (Alangüllü) thermal water.

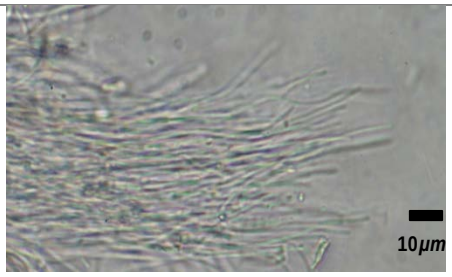
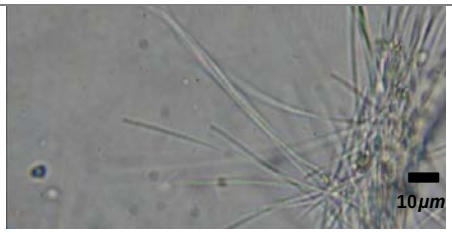
Parameter	**pH**	**EC (µhos/cm)**	**Cl^- (me/l)**	**CO_3^{2-} (me/l)**	**HCO_3 (me/l)**	**SO_4^{2-} (me/l)**	**$Ca^{2+} + Mg^{2+}$ (me/l)**	**K^+ (me/l)**	**Na^+ (me/l)**
Value	7,90	8500	39,18	Trace	24,00	15,89	2,74	2,55	81,26

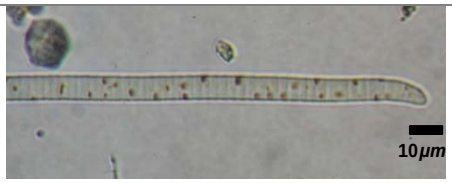
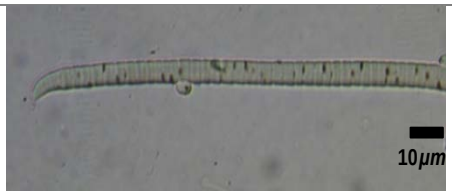
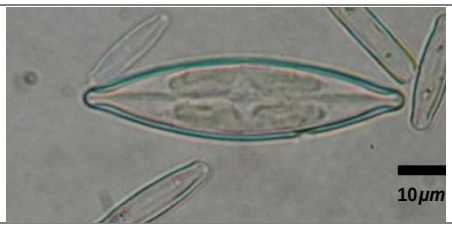
3 Results

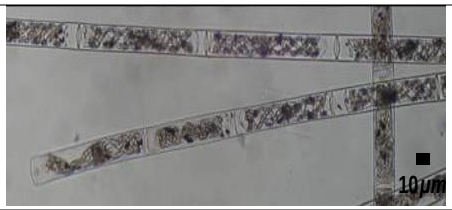
The present study reports a total of 27 taxa (Table 3) of the Germencik (Alangüllü) thermal water source (21 Cyanobacteria, 5 Bacillariophyceae and 1 Conjugatophyceae). As it can be seen from Table 3, *Leptolyngbya subtilis* (West) Anagnostidis, *Leptolyngbya* cf. *thermobia* Anagnostidis and *Heteroleibleinia kossinskajae* (Elenkin) Anagnostidis & Komárek are new report for Turkish Algae flora. Also data are also given concerning the photos, the morphological and ecological characteristics of each taxa.

Table 3. The taxonomy, the photos, the morphological and ecological characteristics of each taxa that spread in the Germencik (Alangüllü) thermal water source.

Taxonomy	Photograph	Morphological and Ecological characteristics
Divisio : Cyanobacteria **Classis** : Cyanophyceae **Ordo** : Chroococcales **Familya** : Synechococcaceae **Genus** : Aphanothece ***A. bullosa* (Meneghini) Rabenhorst**		Mucilaginous and macroscopic size colonies in olive green colour. Cells pale blue-green colour, cylindrical or oval shape and 4 µm wide, 6 µm long.
Familya : Chroococcaceae **Genus** : Chroococcus ***C. membraninus* (Meneghini) Nägeli**		Mucilaginous envelope wide and colourless. Cells arrangement 2-4 in colonies. Hemispherical cells, 15 µm long and 10 µm wide. Among other Cyanobacteria.
Genus :Cyanosarcina ***Cyanosarcina sp.***		Small colonies consists of 2-16 cells. Colonies more or less spherical, pale blue-green colour. Irregularly aggregated cells packet with colourless mucilage. Among other Cyanobacteria.
Ordo : Oscillatoriales **Familya** : Pseudanabaenaceae **Genus** : Pseudanabaena ***P. mucicola* (Naumann & Huber-Pestalozzi) Schwabe**		Short trichomes arrangend in 4-6 celled. Trichomes, in pale blue-green colour and straight. Clearly constricted at cross-walls. Cells, 1,7-2,5 µm wide and 2-5 µm long.
***P. minima* (G.S.An) Anagnostidis**		Straight and very long filaments densed in clusters. Pale blue-green cells 1,5-2,5 µm wide and 4 µm long. Constricted at translucent cross-walls.
***P. catenata* Lauterborn**		Motile trichomes in clusters or in small thallus. Long and straight trichomes, 1,5-2 µm wide and 3-5 µm long. Constricted at translucent cross-walls.
***P. galeata* Böcher**		Filaments in small clusters. Trichomes more or less straight and entangled the others. 1-2 µm wide isodiametric cells. Clearly constricted at cross-walls.
Genus : Jaaginema		

J. angustissimum **(West & G.S.West) Anagnostidis & Komárek**		Trichomes in crowded in clusters, more or less straight or curved. Cells in blue-green colours, 1 µm wide and 2,5-3 µm long.
Genus : Spirulina ***S. major*** **Kützing ex Gomont**		Solitary trichomes, among other algae. In dark blue-green colours. Regularly spirally coiled. Rapid gliding motile.
S. subsalsa **Oersted ex Gomont**		Solitary trichomes very long and motile. Regularly spirally coiled. Among other algae and Cyanobacteria.
S. robusta **Welsh**		Solitary trichomes not very long. Densely and regularly spirally coiled. Among other algae and Cyanobacteria.
Genus : Leptolyngbya ***L. subtilis**** **(West) Anagnostidis**		Filaments more or less straight or slightly curved and in clusters. Sheaths thin and colourless. Cells 1,8 µm wide, 1,5-2,5 µm long, in blue-green colours.
L. **cf.** ***thermobia**** **Anagnostidis**		Filaments irregularly screw-like coiled and 2-2,5 µm wide. Sheaths thin and colourless. The length of the cells 1 or 2 times than the width. In the form of colony with other filamentous cyanobacteria members.
Genus : Heteroleibleinia ***H. kossinskajae**** **(Elenkin) Anagnostidis & Komárek**		Long filaments attached by one end to the other algae or cyanobacteria. Straight filaments 2 µm wide and 4-5 µm long, in pale blue-green colours.

Ordo : Oscillatoriales **Familya** : Phormidiaceae **Genus** : Phormidium ***Phormidium sp.***		Trichomes with thin, colourless and firm sheaths. Cells, granular and in blue-green colour, 3 µm wide and 5-5,5 µm long. Among other algae.
***P. boryanum* (Bory ex Gomont) Anagnostidis & Komárek**		Olive-green colour trichomes regulary screw-like coiled and 7,5 µm wide. Granular cells 2,5-3 µm long. Apical cell acute. Cross-walls distinc and constricted.
***P. chalybeum* (Mertens ex Gomont) Anagnostidis & Komárek**		Straight trichomes in blue-green colour and 7,5 µm wide. Cells 3,5-4 µm long. Apical cells slightly bent.
P. inundatum **Kützing ex Gomont**		Thallus, thin and in dark blue-green colour. Filaments very slighty curved, 3 µm wide. Cells, granulated, in blue-green colour and 9 µm long. Cross-walls distinc and not constricted.
P. granulatum **(Gardner) Anagnostidis**		Solitary and straight trichomes among other algae. Cells, 4 µm wide and 6 µm long. Granules at the cross-walls.
Familya : Microcoleaceae **Genus** : Kamptonema ***K. okenii* (C.Agardh ex Gomont) Strunecký, Komárek & J.Smarda**		Long and straight trichomes 6 µm wide. Granuler cells in blue-green colour and 4,5-5 µm long. Apical cells long and bent.
Familya : Oscillatoriaceae **Genus** : Oscillatoria ***O. subbrevis* Schmidle**		Solitary trichomes 6-9 µm wide. More or less constricted at cross-walls. Cells shorter than width. Apical cells rounded.
Divisio : Bacillariophyta **Classis** : Bacillariophyceae **Ordo** : Naviculales **Familya** : Naviculaceae **Genus** : Navicula ***Navicula sp.***		Cells oval-shaped but two ends rounded narrow. Two big chloroplasts seen very distinctly. Cells, 20-25 µm long and 6-7 µm wide.

Ordo : Cocconeidales **Familya** : Achnanthidiaceae **Genus** : Achnanthidium ***A. minutissimum* (Kützing) Czarnecki**		Cells, ovoid-fusiform shaped, small size, 10-12 µm long and 4-6 µm wide. Valve without raphe.
Ordo : Thalassiophysales **Familya** : Catenulaceae **Genus** : Amphora ***A. ovalis* (Kützing) Kützing**		Two valves strongly arched, so one way frustules look like Cymbella. Both valves with raphes. Cells, 40-55 µm long and not measured width.
Ordo : Rhopalodiales **Familya** : Rhopalodiaceae **Genus** : Rhopalodia ***R. gibba* (Ehrenberg) Otto Müller**		Cells are trihedral. Frustules appears rectangular. Cells, with one raphe, 120-135 µm long and 12-13 µm wide.
Ordo : Surilellales **Familya** : Surilellaceae **Genus** : Surilella ***Surilella sp.***		Cells, large and ovoid or drop shaped. Valves margin looks like costate. Cells, 120-130 µm long and 80-90 µm wide.
Classis : Conjugatophyceae **Ordo** : Zygnematales **Familya** : Zygnemataceae **Genus** : Spirogyra ***Spirogyra sp.***		Filaments forming dark green cushions. Cells with 3 helical chloroplasts and more pirenoids. Conjugation not observed.

* New report for Turkish Algae flora.

4 Discussion and Conclusion

Thermal waters are quite extreme habitats for living organisms. The most important cause of this is the high temperature. In addition, thermal waters form a special living environment with a variety of materials dissolved in their constituents. The living group that best adapts to these habitats is other algal groups after cyanobacteria which are primarily photosynthetic prokaryotes. For this reason, determining the algae diversity of these areas is important in this case. However, when the literature is examined, it is seen that there are not enough studies about the biodiversity of the thermal areas in our country (Table 1). With this study, algae diversity of the thermal water source has been identified.

It is seen that the number of species determined by this study is relatively high compared to other studies done in our country (Table 3). The variety of sampling stations we work with, the 12 month monitoring study and the identification of live samples are the most important factors in the high number of species.

Cyanobacteria members are organisms that a high tolerance to ecological factors. So they widely distributed. In this study, 3 taxa (all members of the cyanobacteria) were described for the first time for the Turkish Algae. *Leptolyngbya subtilis* described from Netherlands [26], Spain [27], Sandwich Islands, Australia, Hawaii and Sri Lanka [22]. This taxon characteristically initially attached by one end to the substrate. Also it's sheaths hyaline and thin.

Leptolyngbya thermobia, reported from thermal waters, especially from salty springs in Greece [28], Hungary [29], Russia [30], Japan, USA and Czech Republic [22]. Our findings indicate the taxonomic

properties of this taxon. Also in literature, there are some confusing between *L. thermobia* Anagnostidis and *L. lagerheimii* Gomont and Gomont, but according to Komárek and Anagnostidis [22]; *L. lagerheimii* records from thermal springs belongs to *L. thermobia*.

Heteroleibleinia kossinskajae shows thin and long flexuous filaments, attached to the substrates by one end. Reported from Israel [31], Britain [32], Romania [33], Russia [34], Korea [35] and New Zealand [36]. Typically known as freshwater, epiphytic on *Cladophora* or other algae. We identified this species as epiphytic on other filamentous cyanobacteria.

Today, unfortunately, as we all well know spa waters and thermal waters are under control due to aesthetic concerns and health risks. For this purpose, it is transported by pipes from the source and is not allowed to see the sun. As a result, these taxa, which are specific to thermal waters (that adapts to extreme living conditions), and their genetic material that may be useful to us in the future is undergoing genetic erosion. The genetic characteristics of these species and the genetic material that may be useful to us in the future (resistance to factors such as temperature, high alkalinity, acidity and radioactivity etc. with recombinant DNA technology) should be determined, isolated and DNA must be stored without genetic erosion.

On the other hand, the identification of algae diversity in such areas will contribute to the creation of cultures and culture collections likely to be obtained from these species. This will create an infrastructure for future biotechnological investigations (biodiesel, food, food additive, bio fertilizer, single cell protein, biological treatment etc.).

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