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SOME TERRESTRIAL ALGAE ON THE SURFACE OF BUILDINGS IN DEBRECEN, HUNGARY

Enikő T-Krasznai[1]*, Zsuzsanna Nemes-Kókai[1], Krisztina Buczkó[2] and Viktória B-Béres[1]

[1]*HUN-REN Centre for Ecological Research, Institute of Aquatic Ecology, Department of Tisza Research, Functional Algology Research Group, H–4026 Debrecen, Bem tér 18/c, Hungary; *torok-krasznai.eniko@ecolres.hu (corresponding author)*
[2]*Department of Botany, Hungarian Natural History Museum, H–1431 Budapest, Pf. 137, Hungary; buczko.krisztina@nhmus.hu*

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Abstract: A total of 19 terrestrial algae were identified from different surfaces of the courtyard of the Hungarian Research Network (HUN-REN) Institute for Nuclear Research in Debrecen. Organisms were identified at the lowest possible taxonomic level. Various species of Cyanobacteria, chlorophytes, charophytes, and diatoms were characteristic components of the studied terrestrial community. Green algae (*Klebsormidium* sp., *Trebouxia* sp., and *Apatococcus* sp.) represent the dominant element in almost all samples mainly on the surfaces of green patches on pavements. Some rare Cyanobacteria species, *Hassallia byssoidea*, *Gloeocapsopsis chroococcoides*, *Gloeocapsopsis pleurocapsoides,* and *Gloeocapsa novacekii* were found on the old artificial surfaces. A member of the Hungarian Red List, *Cylindrocystis brebissonii* was also found under an old transformer.

Key words: artificial surfaces, *Gloeocapsa*, *Gloeocapsopsis*, *Hassallia*, red list, terrestris algae

INTRODUCTION

It has long been known that algae are cosmopolitan (Wehr *et al.* 2015) and they can occupy all habitats in the world from the water through the surface of various terrestrial environments (Rindi and Guiry 2004). Terrestrial algae are an ecological group of algae that "spend their whole life cycle in terrestrial habitats such as soil, rocks, snow, and ice and can also live on animals and plants" (Darienko and Friedl 2021). They are usually referred to as aeroterrestrial, aerophilic or aerial organisms (Lakatos and Strieth 2017), however, terrestrial algae comprise not only aerial forms. Whereas aerial algae live on stable exposed surfaces above the soil (Lopez-Bautista *et al.* 2007), other terrestrial groups occupy even much more extreme habitats (e.g., endolithic groups – Hoffmann 1989). Terrestrial algae can play a pivotal role in the terrestrial environment, serving as carbon storage (Rindi and Guiry 2004). Additionally, they provide important ecological func-

tions such as oxygen production and nutrient cycling. Furthermore, they possess an array of valuable bioactive compounds, which have the potential to be utilized in pharmaceutical and biotechnological applications (Lakatos and Strieth 2017).

In Hungary, research on terrestrial algae started in the last century, in the 1930s (Fehér 1936). Many Hungarian algologists have undertaken research on terrestrial algae (e.g., Kiss 1959, Kol 1964, Komáromy 1976*a*), resulting in extensive literature on the biology, ecology, and taxonomy of these organisms (Leposssa 2002). In the past, the terrestrial algal flora of Hungary has been studied from different floristic and ecological perspectives mainly focusing on the algal flora of astatic salt lakes (Kiss 1974, Komáromy 1980, V.-Varga 1962), the algal synusia of calcareous sandy soils (Komáromy 1976*a*, Komáromy and Padisák 1999), and the soil algal flora of mountains (Komáromy 1976*b*) or caves (Buczkó and Rajczy 1989, Kol 1964).

Unfortunately, compared to previous years, there is less and less recent literature on the distribution of terrestrial algae in Hungary.

Old buildings and pavements with shaded, weather-sheltered conditions can favour the distribution of terrestrial algal assemblages (Rindi and Guiry 2004, Rindi *et al.* 2008). Many of these habitats can be found in Debrecen, an ancient city in the eastern part of Hungary. However, there are no previous data of terrestrial algae assemblages from this area.

The Centre for Ecological Research, Department of Tisza Research is located at the HUN-REN Institute for Nuclear Research (abbreviated as ATOMKI) in the centre of Debrecen. The oldest part of the building complex of ATOMKI was built in 1954, while the youngest in 1984 (www.atomki.hu). Thus, the area can provide old surfaces with shade and large green patches created by high humidity at the base of walls or pavements. Our goal was to study the small-scale patchiness of different habitats in the case of old artificial surfaces in urban areas.

MATERIAL AND METHODS

Terrestrial algal samples were collected from 10 various sampling points of ATOMKI courtyard in Debrecen, on several occasions in late summer 2023 (Fig. 1). After a heavy rainfall, samples were collected with toothbrushes from different artificial environments and surfaces (Fig. 2) as slate building, concrete and stone walls (Table 1). The fresh samples were immediately studied at 100–1,000× magnification using a Zeiss Axio Observer 7 inverted microscope and the observed species were documented by a Canon EOS R6 digital camera. Organisms were identified at the lowest possible taxonomic level. Most recent accepted name of taxa was considered by AlgaeBase (Guiry and Guiry 2023). The Komárek

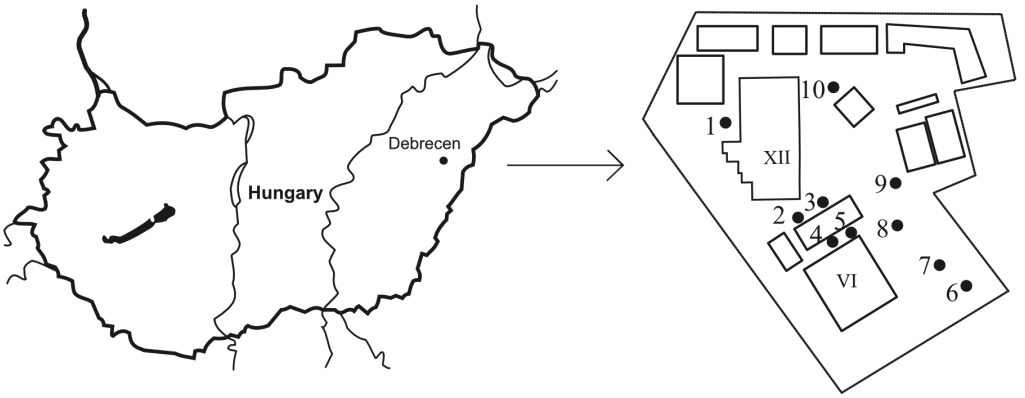

Fig. 1. The map of the sampling area in the courtyard of ATOMKI, Debrecen. Numbers of sampling points are in Table 1.

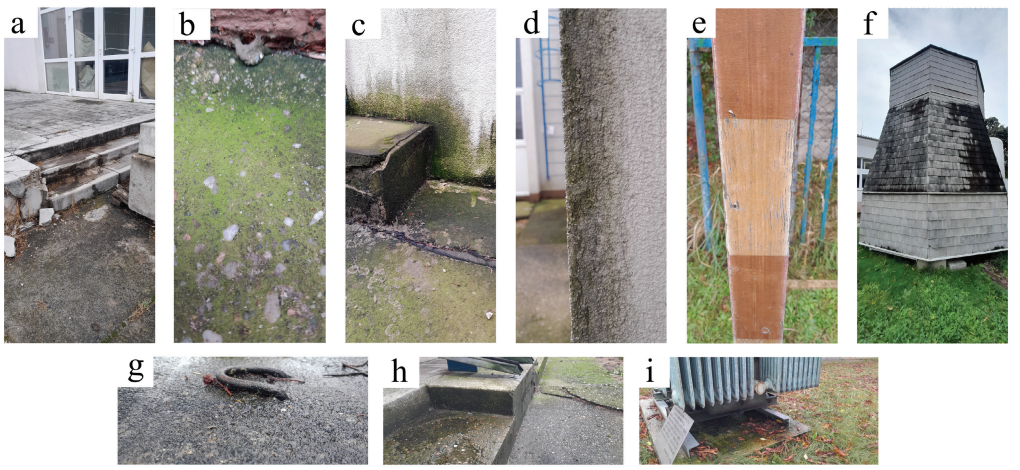

Fig. 2. Photos of some sampling points in the courtyard of ATOMKI, Debrecen. – a) steps next to the building XII; b) pavement of building VI; c) the base of wall of the northern part of building VI; d) wall of the building VI; e) football clay court; f) slate building; g) concrete slab; h) stairs in front of the building VI; i) under an old transformer.

and Anagnostidis (1999) and Hauer (2007) were used for references to taxa descriptions. Evaluation of rarity of the microflora was based on the Hungarian Red List of Algae (Németh 2005).

RESULTS

A total of 19 taxa of eukaryotic algae and Cyanobacteria were identified and their localities are listed in Table 2.

Table 1. List of sampling points sampled in this study.

No.	Locality description	Substrata
1	steps next to the building XII, western locality, shaded	concrete
2	the base of the wall of the northern part of building VI, shaded	stone wall/concrete
3	stairs in front of the building VI, northern locality, shaded	stone/concrete
4	wall of the building VI, northern locality, sunny	stone wall
5	pavement of building VI, northern locality, shaded	concrete
6	wooden football goalpost, sunny	wood
7	football clay court, sunny	clay
8	concrete slab, sunny	concrete
9	slate building, sunny	slate
10	under an old transformer, northern locality, shaded	concrete

Table 2. List of Cyanobacteria and algae identified in the sampling points in the area of ATOMKI, Debrecen. Numbers are in Table 1. New taxa to the flora of Hungary are marked with an asterisk.

Species names	1	2	3	4	5	6	7	8	9	10
Cyanobacteriota										
Calothrix parietina Thuret ex Bornet et Flahault	+		+							
**Gloeocapsa novacekii* Komárek et Anagnotidis	+					+		+	+	
Gloeocapsa sp.	+									
Gloeocapsopsis chroococcoides (Novácek) Komárek								+	+	
**Gloeocapsopsis pleurocapsoides* (Novácek) Komárek et Anagnostidis ex Komárek								+	+	
Hassallia byssoidea Hassall ex Bornet et Flahault	+							+		
cf. *Leptolyngbya* sp.	+									
Nostoc commune Vaucher ex Bornet et Flahault	+						+			
Phormidium sp. (7.5 μm)		+								+
Phormidium sp. (6 μm)										+
Oscillatoria sp.										+
Heterokontophyta										
cf. *Achnanthes inflata* (Kützing) Grunow			+							
Hantzschia abundans Lange-Bertalot										+
Pinnularia borealis Ehrenberg			+							
Chlorophyta										
Apatococcus lobatus (Chodat) J. B. Petersen		+		+						+
Haematococcus lacustris (Girod-Chantrans) Rostafinski				+						+
Trebouxia sp.		+	+	+		+				
Charophyta										
Klebsormidium flaccidum (Kützing) P. C. Silva, Mattox et W. H. Blackwell	+	+	+		+					+
Cylindrocystis brebissonii (Ralfs) De Bary										+
Total species number	7	4	5	3	1	2	1	4	3	8

The samples taken from the green patches of pavements or the base of the wall (Fig. 2b, c) were dominated by *Klebsormidium* filaments, which is common and widespread in terrestrial assemblages (Rindi and Guiry 2004). The *Klebsormidium* filaments created dense mats on the surface of the sampling points mentioned above. This observation is consistent with the affinity of *Klebsormidium* for concrete surfaces, in particular, moist and shaded concrete surfaces have been identified as preferred habitat for these taxa in several European cities (Rindi and Guiry 2004).

The composition of the assemblages taken from the brownish- and orange-coloured surfaces (Fig. 2e, f, g) such as Localities 6, 8, 9 was characterized by the dominance of a few taxa. The following species that previously have rarely been mentioned or have not been reported at all from Hungary, were found in these sampling points. These algae dominated the surface of the concrete slab and slate building, which contradicts previous findings (mostly described from serpentine rocks; Hauer 2007). Two of the identified species are recorded for the first time in Hungary (*Gloeocapsa novacekii* Komárek et Anagnostidis and *Gloeocapsopsis pleurocapsoides* (Nováček) Komárek et Anagnostidis). *Gloeocapsopsis chroococcoides* (Nováček) Komárek and *Hassallia byssoidea* Hassall ex Bornet et Flahault are rare and noteworthy taxa in Hungary. Moreover, under an old transformer (Figs 1, 2i), *Cylindrocystis brebissonii* (Ralfs) De Bary, an endangered species according to the Hungarian Red List (Németh 2005) was found (Fig. 3a).

ENUMERATION OF TAXA NEW FOR THE HUNGARIAN FLORA

Gloeocapsa novacekii Komárek et Anagnostidis (Fig. 3e, f)

Description: Cells spherical and olive green. More or less spherical slimy colonies are microscopic, composed of 2–4-celled sub-colonies, coloured red of different intensities and often granulated.

Cell dimension: 4–8 μm in diameter.

Ecological data: This species was found on the surface of fast drying concrete (sampling points 1, 8), wooden football goalpost (sampling point 6), and slate (sampling point 9) (Fig. 1, Fig. 2a, e, f, g). It was found commonly in the Czech Republic on partly shaded, periodically moistened limestone walls (Hauer 2007).

Previous occurrences in Hungary: New to the Hungarian flora!

Distribution: Arctic (Patova *et al.* 2015), Russia (Arctic) (Shalygin 2012), Svalbard (Spitsbergen) (Davydov 2021). – Europe*:* Czech Republic

(Kaštovský *et al.* 2018), Romania (Caraus 2017), Saxony (Germany) (Doege *et al.* 2022), Scandinavia (Karlson *et al.* 2020), and Serbia (Ljaljević-Grbić *et al.* 2010)

Gloeocapsopsis pleurocapsoides (Nováček) Komárek et Anagnostidis, Arch. (Fig. 3d)

Syn.: *Gloeocapsa pleurocapsoides* Nováček

Description: Cells are spherical, oval to irregular. The species is found in the form of dense packs of brownish polygonal cells within a thin, firm envelope. The spherical to amorphous gelatinous colonies, coloured in different intensities of brownish yellow are microscopic, later macroscopic.

Cell dimension: 4–8 μm in diameter.

Ecological data: It was found on the sunny side of the surface of concrete and slate (sampling points 8, 9; Fig. 1, Fig. 2f, g). It occurs on partly shaded, periodically moistened limestone, or serpentine walls and outcrops and also commonly occurs on wet concrete walls (Hauer 2007).

Previous occurrences in Hungary: New to the flora of Hungary!

Distribution: It has a worldwide distribution.

RARE TAXA IN THE HUNGARIAN FLORA

Gloeocapsopsis chroococcoides (Nováček) Komárek (Fig. 3c)

Syn.: *Gloeocapsa chroococcoides* Nováček

Description: Cells are irregularly spherical, oval or polygonal. Colourless or pale green to blackish, sometimes a slightly reddish to violet sheath follows the outline of the cell and the surface is sometimes granulated. Microscopic colonies vary from spherical to irregular.

Cell dimension: 10–15(–18) μm in diameter.

Ecological data: It was found on the sunny side of the surface of concrete and slate (sampling points 8, 9; Fig. 1, Fig. 2f, g). It was originally described from serpentine rocks in western Moravia (Czech Republic; Hauer 2007). This species is rare both in the region and in the world.

Previous occurrences in Hungary: Hajdúság and Nyírség: Soda-lakes (Kiss 1983) – Körös–Maros Interfluve (Kiss 1972).

Distribution: Czech Republic (Kaštovský *et al.* 2018), India (Chatterjee 2019), Romania (Caraus 2017), Russia (Arctic) (Shalygin 2012) and Ukraine (Barinova *et al.* 2019).

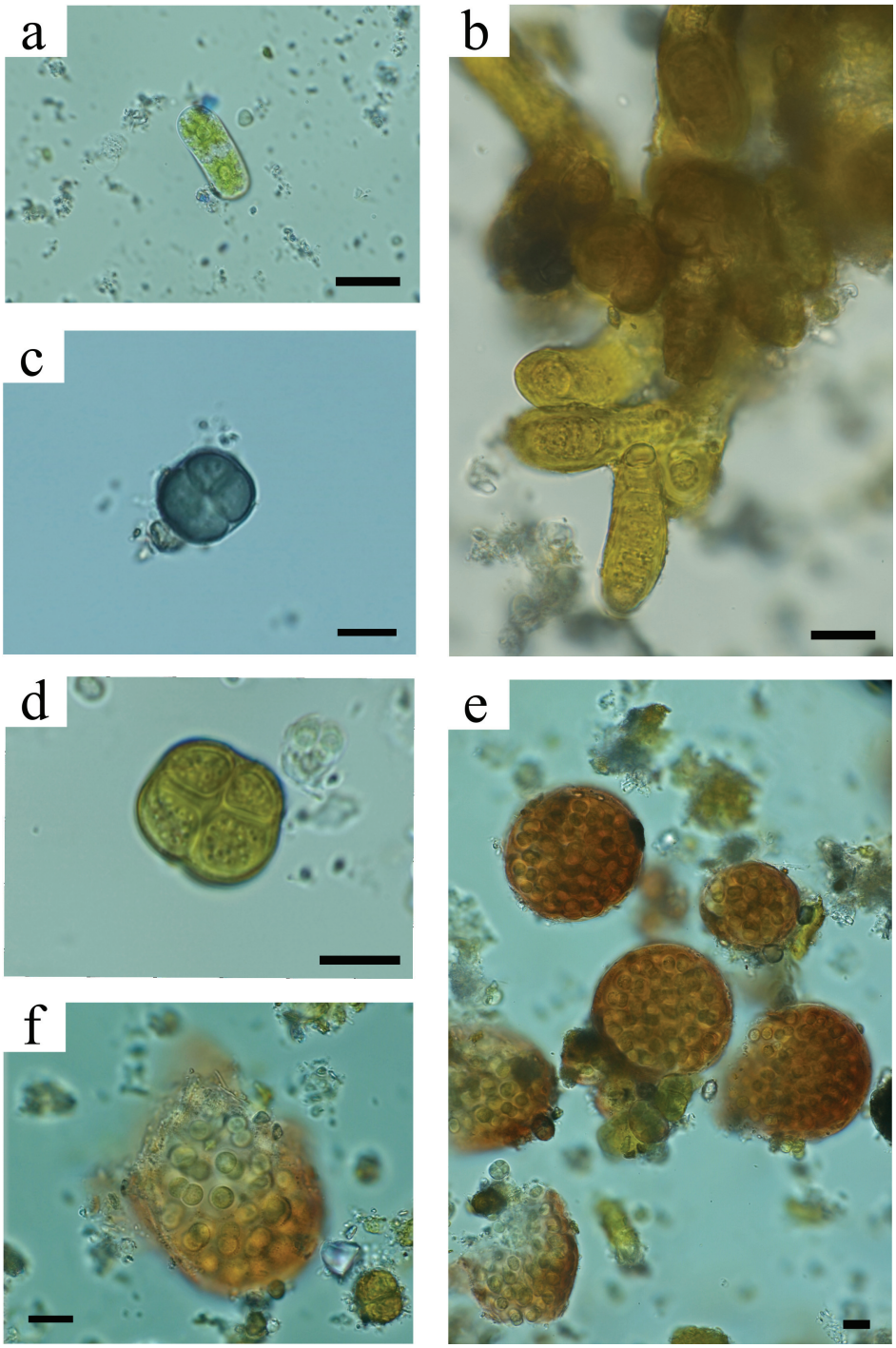

Fig. 3. Photos of the rare species in the courtyard of ATOMKI, Debrecen. – a) *Cylindrocystis brebissonii*; b) *Hassallia byssoidea*; c) *Gloeocapsopsis chroococcoides*; d) *Gloeocapsopsis pleurocapsoides*; e–f) *Gloeocapsa novacekii.* Scale bar 10 µm.

Hassallia byssoidea Hassall ex Bornet et Flahault
(Fig. 3b)

Syn.: *Scytonema byssoideum* C. Agardh, *Tolypothrix byssoidea* (C. Agardh) Kirchner

Description: Cells are short barrel-shaped. Heterocytes are hemispherical to oval. Akinetes are absent. Falsely branched with solitary lateral branches, heteropolar. Filaments are in brownish sheaths. Trichomes constricted at the cross walls, not attenuated towards the ends. Sheaths up to 4 μm wide, narrowing towards the ends.

Cell dimension: 8–11 μm wide, 2–3 times wider than long.

Ecological data: This species was found on partially shaded, intermittently wet concrete surfaces (sampling points 1, 8; Fig. 1, Fig. 2a, g).

Previous occurrences in Hungary: Kiskunság (Komáromy and Padisák 1999).

Distribution: It has a worldwide distribution.

DISCUSSION

Among algae the terrestrial ones are usually paid less attention in research and monitoring works. The use of algae in water biomonitoring is widespread and several official rules obligate the countries to investigate the aquatic algae regularly. The most relevant regulation is the Water Framework Directive. However, terrestrial algae can play a pivotal role in the function of terrestrial environments, including agricultural and natural habitats, so their investigation should not be a negligible field of algology.

Usually, the physical structure of these algae is very simple, typically with a few morphological types (unicellular, unicellular filamentous, sarcinoid colony). They provide very few taxonomically and systematically useful features, therefore the identification and classification of terrestrial algae are complicated. Thus, in several taxa only the genus level could be identified without extra efforts like cultivation and molecular methods. However, some species can be safely identified, and they are reliable records for the flora of a country.

The species, *Cylindrocystis brebissonii* has a worldwide distribution, interestingly, in our study it was found in terrestrial environment. This taxon was published from several Hungarian localities, from soil (Fehér 1948), from caves (Kol 1957, 1962, 1964) including urban environment (Franzé 1893) or close to running water (Szemes 1967, Kol and Varga 1960, Kol 1970) as well as from mires (e. g. Kol 1967), but its presence in the Hungarian flora fulfils the criteria to be a member of the Hungarian Red List (Németh 2025).

* * *

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Összefoglaló: A debreceni Atommag Kutató Intézet udvarának különböző felszíneiről 19 szárazföldi algát azonosítottunk. Az egyedeket a lehető legalacsonyabb rendszertani szinten azonosítottuk. A vizsgált szárazföldi közösségek jellegzetes összetevői a cianobaktériumok, a zöldalgák és a diatómák különböző fajai voltak. A zöld foltos járdák felületén a zöld algák (*Klebsormidium* sp., *Trebouxia* sp., *Apatococcus* sp.) voltak a jellegzetesek. Néhány ritka cianobaktérium faj, a *Hassallia byssoidea*, a *Gloeocapsopsis chroococcoides*, a *Gloeocapsopsis pleurocapsoides* és a *Gloeocapsa novacekii* mesterséges felületen volt megtalálható. Egy régi transzformátor alatt a magyar Vörös Listán szereplő *Cylindrocystis brebissonii*-t is megtaláltuk.

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