

⟨Original article⟩

## A Study of Seven Unrecorded Species of Benthic and Subaerophytic Cyanobacteria (Cyanophyceae, Cyanophyta) in Korea

Byoung Cheol Yim, Jee Hwan Kim<sup>1</sup>, Sung Ro Yoon, Nam Ju Lee and Ok Min Lee\*

Department of Life Science, College of Natural Science, Kyonggi University, Suwon 16227, Republic of Korea

<sup>1</sup>Bioresources Culture Collection Division, Nakdonggang National Institute of

Biological Resources, Sangju 37242, Republic of Korea

**Abstract** - Samples were collected from benthic and subaerophytic habitats of fresh and brackish water in Korea from April 2017 to April 2018. Accordingly, three genera and seven species were newly recorded in Korea. Three unrecorded genera were *Cephalothrix*, *Cyanophanon* and *Toxifilum*, and seven species were *Anagnostidinema pseudacutissimum*, *Calothrix elenkinii*, *Cephalothrix komarekiana*, *Cyanophanon mirabile*, *Cyanosarcina chroococcoides*, *Leptolyngbya ectocarpus* and *Toxifilum mysidocida*. *Anagnostidinema pseudacutissimum* and *Cephalothrix komarekiana* had been previously reported to inhabit freshwater, but these were found to be present in brackish water during the period of the present study. Also, *Cyanosarcina chroococcoides* previously reported to inhabit moorland waters and swamps, were found to be present in subaerophytic habitat.

**Keywords** : benthic, brackish water, cyanobacteria, subaerophytic

### INTRODUCTION

Benthic cyanobacteria are classified according to the substrates; epiphytic (submerged plants or other algae), epilithic (rocks or stones), epipellic (mud) and epizoic (crustacean or arthropod). Some of cyanobacteria that have symbiotic relationship with lichen or bryophytes exposed to the atmosphere (Goyal 1997). Rocks exposed to the atmosphere are inhabited by extremophilic cyanobacteria that play a basic role as primary producers in a variety of subaerial habitats such as cliffs and pinnacles of dry and humid regions (Pentecost and Whitton 2000), hot and cold deserts (Wynn-Williams 2000; Vincent 2007) and caves (Hoffmann 2002), and might contribute to the future colonization of other planets (Grilli Caiola and Billi 2007; Billi 2012).

Cyanobacteria have both positive and negative influences on human and environment. They are an important compo-

nent of microbial food webs and grazed biomass in water environments (Gonzalez *et al.* 1998; Charpy 2005). *Spirulina* had been used to food for livestock and human, and they are being developed as substitutional foods for their high content of protein, vitamin, mineral and so on (Graham *et al.* 2009).

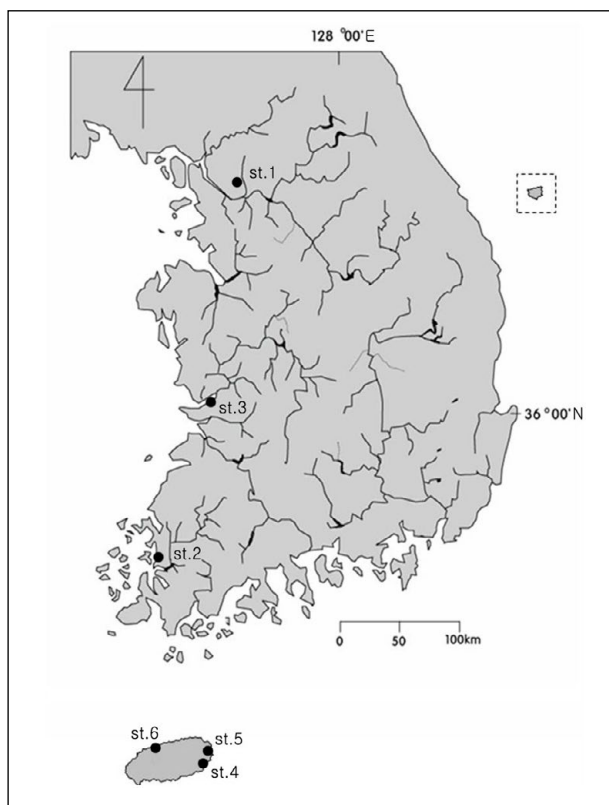
But nowadays, freshwater habitats are threatened worldwide because of cyanobacteria, such as *Oscillatoria*, and *Aphanizomenon*. They produces odorous materials like Geosmin and 2-MIB (Robarts and Zohary 1987; Codd 1995; Graham *et al.* 2009; Whitton 2012). Therefore, continuous researches of cyanobacteria, especially *Microcystis*, *Anabaena*, *Oscillatoria*, and *Aphanizomenon* are being conducted worldwide (Park and Kim 1995; Park 2005; Lee *et al.* 2017).

The 4,617 taxa of cyanobacteria have been reported to AlgaeBase (Guiry and Guiry 2018), and 377 taxa have been reported in Korea (Kim 2015; Song and Lee 2017; Yim *et al.* 2017). *Cephalothrix* and *Cyanophanon* have been reported each 2 taxa and *Toxifilum* reported 1 taxa in world-

\* Corresponding author: Ok Min Lee, Tel. 031-249-9643,  
Fax. 031-241-0860, E-mail. omlee@kgu.ac.kr

wide (Guiry and Guiry 2018).

For this study, we collected unrecorded cyanobacteria from fresh and brackish waters to add the cyanophycean flora of Korea.



**Fig. 1.** The map showing the six sampling sites in Korea from April 2017 to April 2018.

**Table 1.** Sampling sites in Korea from April 2017 to April 2018

Site	Local name	Latitude (N)	Longitude (E)
st.1	33, Dobong-ro, 157-gil, Dobong-gu, Seoul	37.673434	127.042158
st.2	58, Madong-gil, Samhyang-eup, Muan-gun, Jeollanam-do	34.845626	126.412473
st.3	598-63, Gyeongam-dong, Gunsan-si, Jeollabuk-do	35.981633	126.727461
st.4	129-1, Sincheon-ri, Seongsan-eup, Seogwipo-si, Jeju-do	33.351350	126.857913
st.5	833-1, Ojo-ri, Seongsan-eup, Seogwipo-si, Jeju-do	33.460851	126.914538
st.6	1956-49, Oedo 2-dong, Jeju-si, Jeju-do	33.493495	126.427391

**Table 2.** The environments of sampling sites from April 2017 to April 2018

Site	Collection date	Environment	Salinity (‰)
st.1	Feb. 10, 2018	Lichen at the wall of residential area	–
st.2	Sep. 1, 2017	Eutrophic and brackish waterway nearby farmlands	0.2
st.3	Apr. 29, 2017	Eutrophic, brackish waterway	3.6
st.4	Apr. 26, 2018	Eutrophic small pond	–
st.5	Apr. 27, 2018	Eutrophic small pond	–
st.6	May 19, 2017	Eutrophic and brackish small pond	11

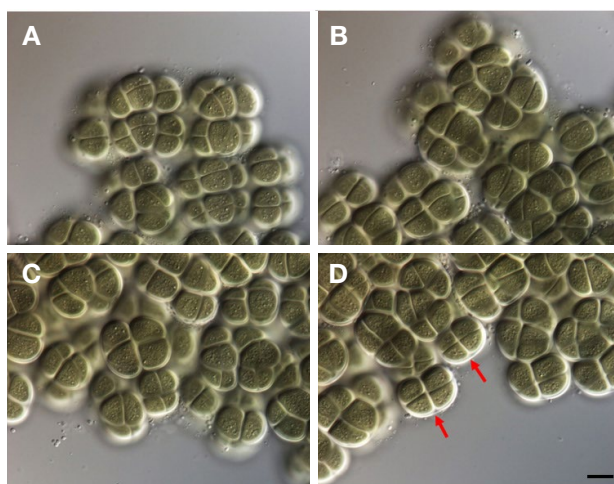
## MATERIALS AND METHODS

We collected benthic and subaerophytic cyanobacteria from six sites in Korea from April 2017 to April 2018 (Fig. 1; Tables 1, 2). Benthic cyanobacteria were collected scrubbing off submerged plants or rocks using soft brush. Subaerophytes were collected from lichen or bryophytes using sharp spatula. Each sample was sealed in sterile bottles and transported them to the laboratory (Crispim *et al.* 2004). Measurement of salinity was performed by marine tester (DMT-10, DYS, Korea).

The samples were examined under BX53 light microscope at  $\times 400$ – $1,000$  (Olympus, Tokyo, Japan) and photographed using AxioCam HRC camera (Carl Zeiss, Oberkochen, Germany). The taxonomic classification system was based on Komárek *et al.* (2014) and Algaebase (Guiry and Guiry 2018). In this study, identification of cyanobacteria referred to Hirose *et al.* (1977), Prescott (1982), Chung (1993), Komárek and Anagnostidis (1999, 2005), John *et al.* (2011) and Komárek (2013).

## RESULTS AND DISCUSSION

Three genera and seven species of benthic and subaerophytic cyanobacteria were newly recorded in Korea. The newly recorded genera were *Cephalothrix*, *Cyanophanon* and *Toxifilum*, and the newly recorded species were *Anag-*



**Fig. 2.** Microscopic images of *Cyanosarcina chroococcoides* (Geitler) Kováčik. The researchers focused on sub-colonies comprising of pellets of cells (A–C) and on fine mucilaginous envelope (D). Scale bar: 10  $\mu$ m.

*nostidinema pseudacutissimum*, *Calothrix elenkinii*, *Cephalothrix komarekiana*, *Cyanophanon mirabile*, *Cyanosarcina chroococcoides*, *Leptolyngbya ectocarpi* and *Toxifilum mysidocida*.

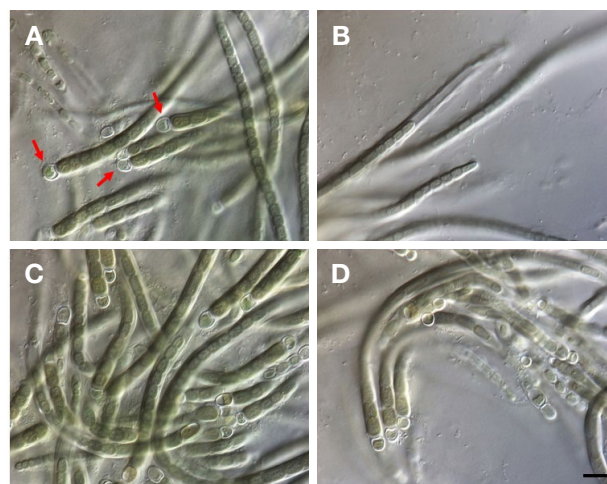
Order Chroococcales Schaffner 1922  
Family Chroococcaceae Rabenhorst 1863  
Genus *Cyanosarcina* Kováčik 1988

***Cyanosarcina chroococcoides* (Geitler) Kováčik 1988 (Fig. 2)**

**Synonym:** *Myxosarcina chroococcoides* Geitler 1927

The colonies are microscopic and shaped subspherical or irregularly rounded with different sizes. The colony is composed of densely and irregularly aggregated packets of cells in different sizes. The mucilaginous envelope that surrounds the colony is thin (about 1  $\mu$ m thick), firm and colourless. The mucilaginous envelope tightly surrounds the cell packets, sometimes diffluent in old colonies. The cell is irregularly rounded and olive-green or blue-green colored. The cell diameter is 8–12  $\mu$ m.

**Ecology:** This species lives in moorland waters and swamps. Maybe they have wide distribution over the whole temperate zone (Komárek and Anagnostidis 1999). In this



**Fig. 3.** Microscopic images of *Calothrix elenkinii* Kossinskaja 2016. The researchers focused on heterocysts (red arrows), basement (A) and apex (B) and showed overall appearance of trichomes (C, D). Scale bar: 10  $\mu$ m.

study, we collected this species from subaerophytic substrate (the wall of residential area).

**Distribution:** Europe: Spain (Alvarez-Cobelas and Gallardo 1988); South America: Argentina (Tell 1985); Asia: Japan (Hirose *et al.* 1977).

**Site of collection:** The wall of residential area, Dobong-gu, Seoul (February 10, 2018).

**Specimen Locality:** ACKU2018MD01

Order Nostocales Borzi 1914  
Family Rivulariaceae Bornet and Flahault 1886  
Genus *Calothrix* Agardh ex Bornet and Flahault 1886

***Calothrix elenkinii* Kossinskaja 1924 (Fig. 3)**

The thallus is composed of elongated clusters, also producing solitary filaments. Filaments exist solitary, in groups or clusters. Filaments are fasciculated, arcuated, and entangled together at the bases. Sheaths are thin, not lamellated, colorless; they are open at the apex and usually longer than the trichomes. The width excluding the sheath is 5.5–7  $\mu$ m at the basements and 5–6.5  $\mu$ m wide at the middle parts. There are solitary heterocysts at the basement's apex, with 4.5–7  $\mu$ m width. At the basements, constricted at the cross-wall strongly appears, but slightly constricted cross-walls appear at the opposite end (apical regions). Trichomes

are blue-green or olive-green colored and apical cells are narrowed and rounded. Cells are quadratic or a little shorter than long, but elongated and longer than wide in the upper part.

**Ecology:** This species appears in freshwater and benthic habitat. They lives in streams and soils (Komárek 2013). We collected it from eutrophic small pond.

**Distribution:** Europe: Spain (Mateo *et al.* 2006); South America: Argentina (Tell 1985); Asia: Russia (Medvedeva and Nikulina 2014).

**Site of collection:** Gotari-mot, Seongsan-eup, Seogwipo-si, Jeju-do (April 26, 2018).

**Specimen Locality:** ACKU2018IR03

Order *Oscillatoriales* Schaffner 1922

Family *Coleofasciculaceae* Komárek, Kastovsky, Mares and Johansen 2014

Genus *Anagnostidinema* Strunecký *et al.* 2017

*Anagnostidinema pseudacutissimum* (Geitler)

Strunecký, Bohunická, J.R. Johansen and J. Komárek 2017 (Fig. 4)

**Synonym:** *Oscillatoria pseudacutissima* Geitler

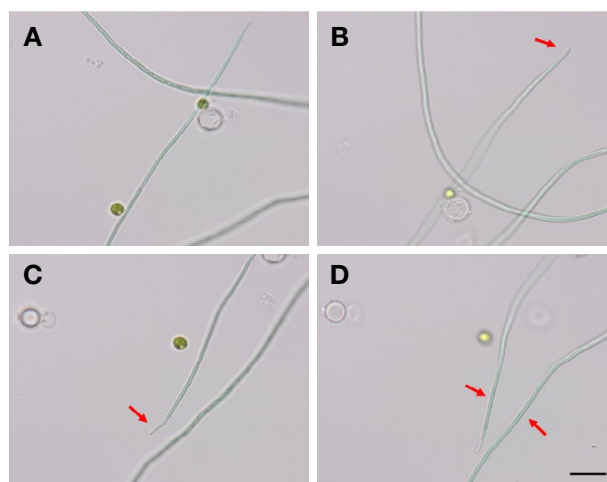
*Phormidium pseudacutissimum* (Geitler) Anagnostidis and Komárek 1988

*Geitlerinema pseudacutissimum* (Geitler) Anagnostidis 1989

The thallus is blue-green colored. Trichomes are straight or slightly coiled and motile with anticlockwise rotation. Trichomes are unconstricted or slightly constricted at cross-walls and slightly attenuated at the ends and bent. Apical cells are hooked and roundly-pointed. Cell contents have prominent carotenoid granules, usually near the cross-walls. Cells are colored bright blue-green and 1.2–3 times longer than wide, with 1.2–1.4  $\mu\text{m}$  width.

**Ecology:** This species appears in freshwater and benthic habitat (Komárek and Anagnostidis 2005). In this study, we collected it from eutrophic and brackish waterway (salinity 0.2‰).

**Distribution:** Europe: Netherlands (Veen *et al.* 2015).



**Fig. 4.** Microscopic images of *Anagnostidinema pseudacutissimum* (Geitler) Strunecký, Bohunická, JR Johansen & J Komárek. The researchers showed overall appearance of trichomes (A) and focused on apex (B, C) and middle parts of trichomes (D). Scale bar: 10  $\mu\text{m}$ .

**Site of collection:** Madong-waterway, Samhyang-eup, Muan-gun, Jeollanam-do (September 1, 2017).

**Specimen Locality:** ACKU2017IR11

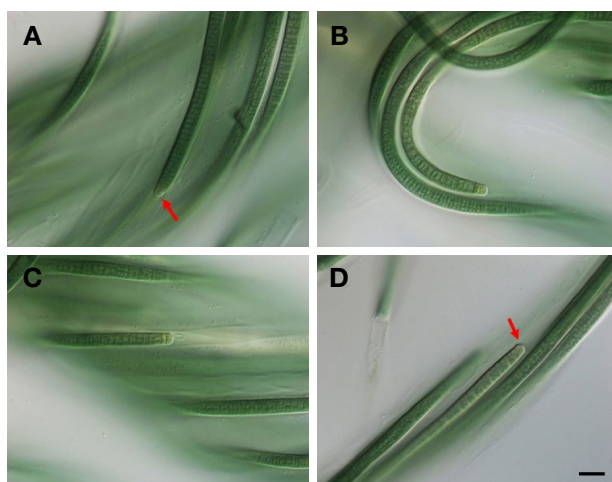
Family *Phormidiaceae* Anagnostidis and Komárek 1988

Genus *Cephalothrix* C.F.S. Malone *et al.* 2015

The thallus is fasciculated and blue-green colored. Trichomes are cylindrical and straight, slightly attenuated, sometimes bent at the end. Trichomes are unconstricted or slightly constricted at the cross-walls. Sheaths are facultative hyaline, firm and attached to trichome or wider. Apical cells are strongly or slightly capitate and sometimes with conical calyptra. Hormogonia formation occurred by biconcave necridic cells. Cells are wider than long, length is 2.0–3.4  $\mu\text{m}$  and width is 4.2–6.5  $\mu\text{m}$ .

*Cephalothrix komarekiana* C.F.S. Malone *et al.* 2015 (Fig. 5)

Filaments are cylindrical and straight, but at the end, bent and slightly attenuated. Filaments are constricted or unconstricted at the cross-walls. Sheaths are facultative hyaline, firm and narrow or wide. Hormogonia formation occurred by biconcave necridic cells. At the end of the cells, capitate slightly or strongly appears. Cell contents have facultative



**Fig. 5.** Microscopic images of *Cephalothrix komarekiana* CFS Malone *et al.* The researchers showed overall bundle of trichomes. The red arrows indicate calyptra. Scale bar: 10  $\mu\text{m}$ .

aerotopes. Cells are wider than long, length is 1.2–2.5  $\mu\text{m}$  and width is 5.5–7  $\mu\text{m}$ .

**Ecology:** This species appears in freshwater and benthic habitat. They lives in an alkaline lake in the Brazilian Pantanal wetlands, Mato Grosso do Sul State, Brazil (Malone *et al.* 2015). In this study, we collected it from brackish small stream (salinity 3.6‰).

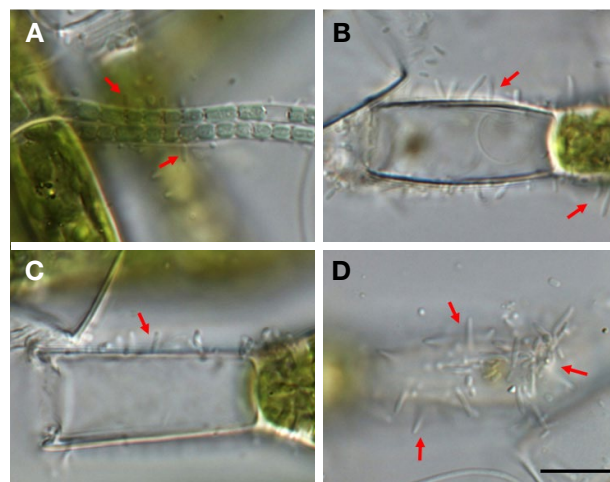
**Distribution:** South America: Brazil (Malone *et al.* 2015).

**Site of collection:** Gyeongpo-gyo, Gyeongam-dong, Gunsan-si, Jeollabuk-do (April 29, 2017).

**Specimen Locality:** ACKU2018IR04

Order Synechococcales Hoffmann, Komárek and Kastovsky 2005  
Family Chamaesiphonaceae Borzi 1878  
Genus *Cyanophanon* Geitler 1955

Cells are heteropolar, and solitary or in groups. They are elongated and attached to the substrate by end. The cells are long cylindrical when old. Cell content is homogeneous or with solitary granules, usually with visible, separate chromatoplasma (lateral position of thylakoids). Cells are pale blue-green, olive-green or light reddish colored. Reproduction is occurred by simultaneous or successive from the apex of the cylindrical cells, rarely along the whole cell;



**Fig. 6.** Microscopic images of *Cyanophanon mirabile* Geitler. They appear to be attached at surface of other cyanobacteria (A) and chlorophytes (B–D). Scale bar: 10  $\mu\text{m}$ .

division by transverse fission. Exocytes are separated one by one, or a great part cell is transformed into a row of exocytes.

#### *Cyanophanon mirabile* Geitler 1955 (Fig. 6)

Cells appear in solitary or in groups. The cells are elongate, cylindrical, straight or arcuated. The apex of the cell is rounded and they divided into a row of cylindrical to barrel-shaped exocytes in the upper parts. Cell contents are usually homogeneous and are pale olive-green, grey-blue or pinkish in color. Cell length is 2.2–4.5  $\mu\text{m}$  and width is 0.7–1.2  $\mu\text{m}$ .

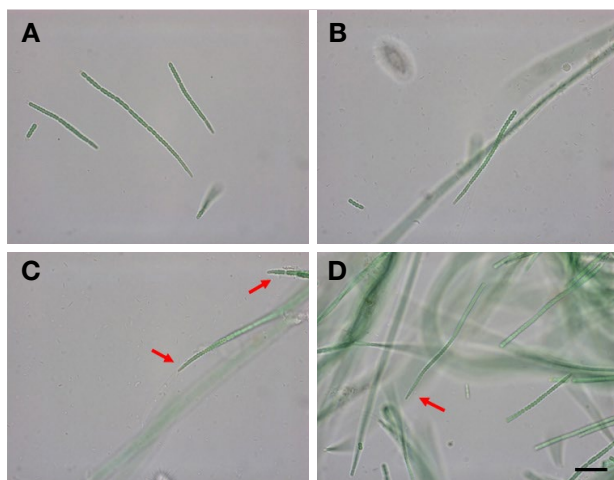
**Ecology:** This species occurs in freshwater species and epiphytes on another filamentous algae. They lives on rocks with flowing water, streams and waterfalls with clear, katharobic water, usually in mountains (Komárek and Anagnostidis 2005). We collected it from eutrophic pond.

**Distribution:** Europe: Czech Republic (Gadea *et al.* 2013).

**Site of collection:** Ojo-ri pond, Seongsan-eup, Seogwi-po-si, Jeju-do (April 27, 2018).

**Specimen Locality:** ACKU2018MD04

Family Leptolyngbyaceae Komárek, Kastovsky, Mares and Johansen 2014  
Genus *Leptolyngbya* Anagnostidis and Komárek 1988



**Fig. 7.** Microscopic images of *Leptolyngbya ectocarpi* (Gomont) Anagnostidis & Komárek. The researchers showed overall appearance of trichomes (A, B) and focused on pointed apex of trichomes (C, D). Scale bar: 10  $\mu$ m.

***Leptolyngbya ectocarpi* (Gomont) Anagnostidis and Komárek 1988 (Fig. 7)**

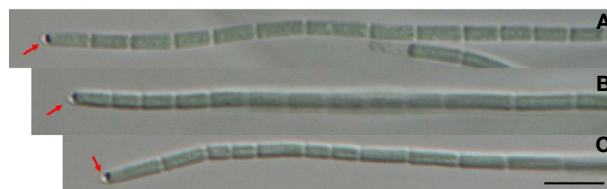
**Synonym:** *Phormidium ectocarpi* Gomont 1899

Thallus is thin, membranaceous and carmine-red or brownish-red in color. Filaments are densely and irregularly entangled or parallel-arranged. Sheaths are mostly colorless, diffuent, mucilaginous, rarely distinct. Trichomes are constricted at the diaphanous, ungranulated cross-walls and are either slightly attenuated. Apical cells are rounded or conical-rounded, lengthened and without calyptra. Cell contents are homogeneous with distinct chromatoplasma. Cells are isodiametric longer than wide. The length is 1.2–1.5  $\mu$ m and the width is 1.4–1.7  $\mu$ m.

**Ecology:** This species appears in marine and epiphytic, epizoic habitat. They lives epiphytic on various seaweeds, epizoic on various animals, mud and walls of glass vessels with marine water widely distributed in littoral and sublittoral zones of coasts (Komárek and Anagnostidis 2005). We collected it from eutrophic brackish pond (salinity 11‰).

**Distribution:** Europe: Britain (Whitton *et al.* 2003), Spain (Gallardo *et al.* 2016); Indian Ocean Islands: Mauritius (Silva and Pienaar 2000).

**Site of collection:** Mai-mot, Oedo 2-dong, Jeju-si, Jeju-do (May 19, 2017).



**Fig. 8.** Microscopic images of *Toxifilum mysidocida* Zimba *et al.* The researchers showed overall appearance of trichomes. The red arrows indicate aerotopes. Scale bar: 10  $\mu$ m.

**Specimen Locality:** ACKU2017IR04

Family Pseudanabaenaceae Anagnostidis and Komárek 1988

Genus *Toxifilum* Zimba, Huang, Foley and Linton 2017

Filaments are composed of a uniseriate trichome. Sheath is usually present, thin, colorless. Filaments are gliding and attenuated at the end. Cells are longer than wide and they have peripheral thylakoids. Filaments and single cells are bright green colored. Both external and cross cell walls are undulated.

***Toxifilum mysidocida* Zimba, Huang, Foley and Linton 2017 (Fig. 8)**

Filaments are rarely solitary and free floating, usually forming clusters or mats on substrate. Filaments are undulated, with thin sheaths, and are unbranched. Filaments are narrowing at the ends and exhibit gliding motility. Cells are cylindrical, with peripherally arranged thylakoids. Polyphosphate bodies and cyanophycin granules occur in cell corners with micro plasmodesmata present between cross cell walls. Cell's length is 3–10  $\mu$ m and width is 2.2–2.5  $\mu$ m.

**Ecology:** This species appears in marine and benthic habitat. They lives in Rincon Bayou salt marsh, Nueces Bay, TX, USA (Zimba *et al.* 2017). We collected it from brackish small stream (salinity 3.6‰).

**Distribution:** North America: Texas (Zimba *et al.* 2017).

**Site of collection:** Gyeongpo-gyo, Gyeongam-dong, Gunsan-si, Jeollabuk-do (April 29, 2017).

**Specimen Locality:** ACKU2018IR05

## ACKNOWLEDGEMENTS

This study was supported by a grant from the National Institute of Biological Resources (NIBR201801205) and the Nakdonggang National Institute of Biological Resources [(The project on collection of freshwater algal strains (Year-2), 2018)], funded by the Ministry of Environment (MOE) of the Republic of Korea.

## REFERENCES

- Billi D. 2012. Anhydrobiotic Rock- Inhabiting Cyanobacteria: Potential for Astrobiology and Biotechnology. pp. 119–132. In *Adaptation of Microbial Life Organisms in Extreme Environments: Research and Application* (Stan-Lotter H eds.). Springer, Wien New York.
- Charpy L. 2005. Importance of photosynthetic picoplankton in coral reef ecosystems. *Vie Milieu*. 55:217–224.
- Chung J. 1993. *The Microscopic Illustrations of the Freshwater Algae of Korea*. Academy Publishing Co., Seoul.
- Codd GA. 1995. Cyanobacterial toxins: occurrence, properties and biological significance. *Water Sci. Technol.* 32:149–156.
- Crispim CA, CC Gaylarde and PM Gaylarde. 2004. Biofilmson church walls in Porto Alegre, RS, Brazil, with special attention to Cyanobacteria. *Int. Biodeterior. Biodegradation* 54:121–124.
- Gadea I, M Rodilla, J Sospedra, S Falco and T Morata. 2013. Seasonal dynamics of the phytoplankton community in the Gandía coastal area, Southern Gulf of Valencia. *Thalassas*. 29:35–58.
- Gallardo T, I Bárbara, J Afonso-Carrillo, R Bermejo, M Altamirano, A Gómez Garreta, MC Barceló Martí, J Rull Lluch, E Ballesteros and J De la Rosa. 2016. Nueva lista crítica de las algas bentónicas marinas de España. *Boletín Informativo de la Sociedad Española de Ficología* 51:7–52.
- Gonzalez JM, J-P Torretón, P Dufour and L Charpy. 1998. Temporal and spatial dynamics of the pelagic microbial food web in an atoll lagoon. *Aquat. Microb. Ecol.* 16:53–64.
- Goyal SK. 1997. Algae and soil environment. *Phykos*. 36:1–13.
- Graham LE, JM Graham and LW Wilcox. 2009. *Algae*. Second edition. Pearson Benjamin Cummings. San Francisco.
- Grilli Caiola M and D Billi. 2007. *Chroococciopsis* from desert to Mars. pp. 555–568. In *Algae and Cyanobacteria in Extreme Environments* (Seckbach J ed.). Springer, Dordrecht.
- Guiry MD and GM Guiry. 2018. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>. accessed on 20 Aug. 2018.
- Hirose HM, T Akiyama, H Imahori, H Kasaki, S Kumano, H Kobayasi, E Takahashi, T Tsumura, M Hirano and T Yamagishi. 1977. *Illustrations of the Japanese Freshwater Algae*. Uchidarokakugo Publishing Co. Ltd., Tokyo.
- Hoffmann L. 2002. Caves and Other Low-light Environments: Aerophytic Photoautotrophic Microorganisms. pp. 835–843. In *Encyclopedia of Environmental Microbiology* (Bitton G ed.). Wiley, New York.
- John DM, BA Whitton and AJ Brook. 2011. *The Freshwater Algal Flora of the British Isles. An Identification Guide to Freshwater and Terrestrial Algae*. Second edition. Cambridge: Cambridge University Press.
- Kim HS. 2015. *National List of Species of Korea: Blue-green Algae*. The National Institute of Biological Resources Pub, Incheon.
- Komárek J. 2013. *Cyanoprokaryota. 3. Heteracystous Genera. Süßwasserflora von Mitteleuropa 19/3*. Spektrum Akademischer Verlag, Heidelberg.
- Komárek J and K Anagnostidis. 1999. *Cyanoprokaryota. 1. Chroococcales. Süßwasserflora von Mitteleuropa 19/1*. Spektrum Akademischer Verlag, Heidelberg.
- Komárek J and K Anagnostidis. 2005. *Cyanoprokaryota. 2. Oscillatoriales. Süßwasserflora von Mitteleuropa 19/2*. Spektrum Akademischer Verlag, Heidelberg.
- Komarek J, J Kastovsky, J Mares and JR Johansen. 2014. Taxonomic classification of cyanoprokaryotes (cyanobacterial genera) 2014, using a polyphasic approach. *Preslia* 86:295–335.
- Lee EH, KS Cho and AJ Son. 2017. Detection and quantification of toxin-producing *Microcystis aeruginosa* strain in water by NanoGene assay. *J. Microbiol. Biotechnol.* 27:808–815 (in Korean).
- Malone CFS, J Rigonato, HD Laughinghouse, ÉC Schmidt, ZL Bouzon, A Wilmotte, MF Fiore and CL Sant’Anna. 2015. *Cephalothrix* gen. nov. (Cyanobacteria): towards an intra-specific phylogenetic evaluation by multilocus analyses. *Int. J. Syst. Evol. Microbiol.* 69:2993–3007.
- Mateo P, I Douterelo, E Berrendero and E Perona. 2006. Physiological differences between two species of cyanobacteria in relation to phosphorus limitation. *J. Phycol.* 42:61–66.
- Medvedeva LA and TV Nikulina. 2014. *Catalogue of Freshwater Algae of the Southern Part of the Russian Far East*. Dalnauka, Vladivostok.
- Park JG. 2005. Developmental characteristic of cyanobacterial bloom in lake Daechong. *Korean J. Environ. Biol.* 23:304–314 (in Korean).

- Park SK and JH Kim. 1995. Cross correlation analysis of environmental factors affecting water-bloom of *Microcystis aeruginosa* (Cyanophyta). Kor. J. Limnol. 28:381–391.
- Pentecost A and BA Whitton. 2000. Limestones. pp. 257–279. In *The Ecology of Cyanobacteria: Their Diversity in Time and Space* (Whitton BA eds.). Kluwer, Dordrecht.
- Prescott GW. 1982. *Algae of the Western Great Lakes area*. WC Brown Company Publishers, USA.
- Robarts RD and T Zohary. 1987. Temperature effects on photosynthetic capacity, respiration and growth-rates of bloom-forming cyanobacteria. N. Z. J. Mar. Freshwat. Res. 21:391–399.
- Silva SMF and RN Pienaar. 2000. Some benthic marine cyanophyceae of Mauritius. Bot. Mar. 43:11–27.
- Song MA and OM Lee. 2017. A study of six newly recorded species of cyanobacteria (Cyanophyceae, Cyanophyta) in Korea. J. Species Res. 6:154–162.
- Tell G. 1985. Catálogo de las algas de agua dulce de la República Argentina. Bibl. Phycol. 70:1–283.
- Veen A, CHJ Hof, FAC Kouwets and T Berkhout. 2015. Rijkswaterstaat Waterdienst, Informatiehuis Water Taxa Watermanagement the Netherlands (TWN). The Netherlands: Laboratory for Hydrobiological Analysis, Rijkswaterstaat. <http://ipt.nlbif.nl/ipt/resource?r=checklist-twn>. accessed on 20 Aug. 2018.
- Vincent WF. 2007. Cold Tolerance in Cyanobacteria and Life in the Cryosphere. pp. 289–301. In *Algae and Cyanobacteria in Extreme Environments* (Seckbach J ed.). Springer, Heidelberg.
- Whitton BA. 2012. *Ecology of Cyanobacteria II: Their Diversity in Space and Time*. Springer, Dordrecht.
- Whitton BA, DM John, MG Kelly and EY Haworth. 2003. *A Coded List of Freshwater Algae of the British Isles*. Second Edition. World-wide Web electronic publication. accessed on 20 Aug. 2018.
- Wynn-Williams DD. 2000. Cyanobacteria in Desert-life at the Limit? pp. 341–366. In *The Ecology of Cyanobacteria. Their Diversity in Time and Space* (Whitton BA eds.). Kluwer Academic Publishers, Dordrecht.
- Yim BC, MA Song, SD Bang, SR Yoon and OM Lee. 2017. Notes on six unrecorded indigenous species of filamentous cyanobacteria (Cyanophyceae, Cyanophyta) in Korea. Korean J. Environ. Biol. 35:296–304.
- Zimba PV, IS Huang, JE Foley and EW Linton. 2017. Identification of a new-to-science cyanobacterium, *Toxifilum mysidocida* gen. nov. and sp. nov. (Cyanobacteria, Cyanophyceae). J. Phycol. 53:188–197.

Received: 20 August 2018

Revised: 7 September 2018

Revision accepted: 10 September 2018