

RESEARCH ARTICLE

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Filamentous cyanoprokaryotes (Cyanoprokaryota/Cyanobacteria) in standing waters of Bulgaria: diversity and ecology

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ABSTRACT

Cyanoprokaryotes are widespread organisms, which dominate in different water basins. In the present study, we have investigated the diversity of this group and related physicochemical parameters in 35 standing water basins in Bulgaria. We found 29 cyanoprokaryotic species, which belong to 13 genera from the orders Synechococcales, Spirulinales and Oscillatoriales. The frequency quotient of each species was calculated. Information about the distribution of the identified species and typology of the water basins is also provided.

Key words: filamentous cyanoprokaryotes, Oscillatoriales, Synechococcales, Spirulinales standing water basins, ecology, distribution

Abbreviations:

- L1 - High mountain glacial lakes
- L2 - Mountain lakes in ecoregion Pontic province
- L4 - Lowland or semi-mountain natural lakes end swamps in Pontic province
- L6 - Riverine wetlands in ecoregion Eastern Balkans
- L7 - Black Sea freshwater coastal lakes
- L8 - Black Sea oligohaline coastal lakes
- L10 - Black Sea euhaline and hyperhaline coastal lakes
- L11 - Large deep reservoirs
- L12 - Small and medium-size semi-mountain reservoirs in Pontic province
- L13 - Small and medium-size semi-mountain reservoirs in Eastern Balkans
- L14 - Large lowland reservoirs with medium depth in Pontic province
- L16 - Small and medium-size lowland reservoirs in Pontic province

Introduction

The algal flora of Bulgaria is characterized by a wide variety of species. Investigations of the algal diversity started 135 years ago (in 1900) with the scientific publications of Petkov (Petkov, 1900). In 1971, Vodenitcharov *et al.* published "Flora of Bulgaria. Algae" (Vodenitcharov *et al.*, 1971). This work included 54 genera with 256 species of cyanoprokaryotes and 169 genera with 757 species of green algae. Data about the algal diversity in Bulgaria were summarized by Vodenitcharov *et al.* (1993) and Temniskova *et al.* (2005). According to them, during the period 1890-2003, in Bulgaria have been found 3065 algal species and 1860 varieties and forms, which belong to 564 genera and 11 orders. Of these, cyanoprokaryotes are 369 species and 85 varieties and forms referred to 58 genera.

Cyanoprokaryotes are characterized with high adaptive plasticity and quick adaptation to light, temperature or other physical and chemical changes in the environment. This is supported by their wide distribution (Anagnostidis & Danielidis, 1982; Economou-Amilli *et al.*, 1984; Hallfors 1984; Komarek, 1985; Anagnostidis & Komárek, 1985; Skulberg & Skulberg, 1985). Cyanoprokaryotes are an interesting object of study since they are a rich source of biologically active substances, including cyanotoxins. Information about the species composition of this taxonomic group is included in the phytoplankton assessment of Bulgarian dams performed by Beshkova *et al.* (2007) and Stoyneva & Temniskova-Topalova (2007).

The biological importance and diversity of this group was demonstrated by Tsanev & Belkinova (2009), Teneva *et al.* (2009; 2010a,b; 2011; 2014), Stoyanov *et al.* (2013).

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The current study presents data about the diversity and ecology of filamentous cyanoprokaryotes that belong to order Oscillatoriales, found in the phytoplankton of standing water basins in Bulgaria.

So far, the studies describing the hydrophilic cyanoprokaryotes and their distribution in Bulgaria are limited. Even more limited is the number of those, which present data about the taxonomic composition and the physicochemical parameters of the water basins.

This study contributes to filling the knowledge of species composition, diversity, environmental parameters and importance of Cyanoprokaryota in Bulgarian water basins.

Materials and Methods

Phytoplankton samples from 35 freshwater basins (dams, lakes and marshes) in Bulgaria were collected by a single sampling in 2009 (Figure 1) and analyzed for species identification.

The typology of the water basins (dams, lakes and swamps) was defined according to System B (Belkinova *et al.*, 2013).

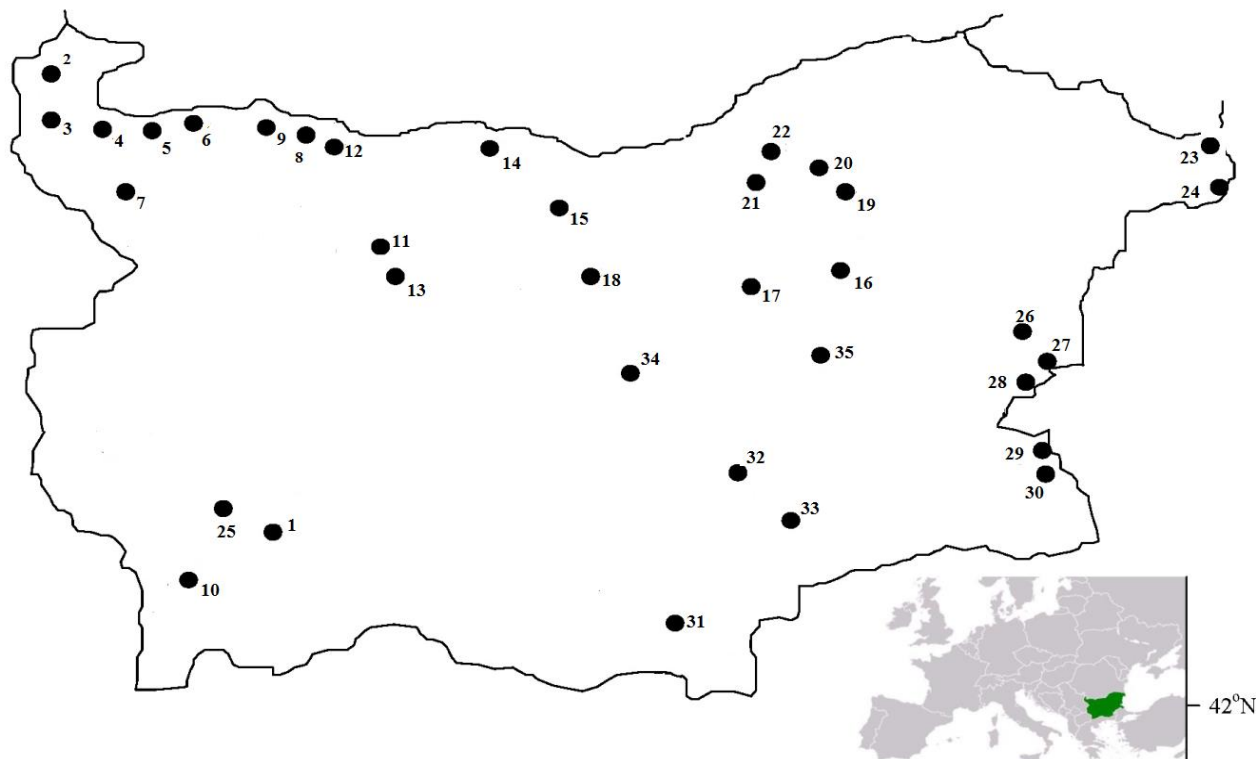


Figure 1. Location of the studied lakes. Legend (national lake type written in parenthesis): 1. Gyorgiysko Lake; 2. Kula Reservoir; 3. Rabisha Reservoir; 4. Drenovets Reservoir; 5. Rasovo Reservoir; 6. Kovachitsa Reservoir; 7. Ogosta Reservoir; 8. Barsina Reservoir; 9. Asparuchov val Reservoir; 10. Bistraka Lake; 11. Enitsa Reservoir; 12. Kruchovitsa Reservoir; 13. Telish Reservoir; 14. Valchovets Reservoir; 15. Kamenets Reservoir; 16. Yastrebino Reservoir; 17. Yovkovtzi Reservoir; 18. Al. Stambolijski Reservoir; 19. Lomtsi Reservoir; 20. Kavatsite Reservoir; 21. Boika Reservoir; 22. Baniska Reservoir; 23. Durankulak swamp; 24. Shabla lake; 25. Redzhepsko Lake; 26. Acheloy Reservoir; 27. Poroy Reservoir; 28. Pomorijsko Lake; 29. Aleru Lake; 30. Yasna polyana Reservoir; 31. Studen kladenets Reservoir; 32. Daskal Atanasovo Reservoir; 33. Ovchi kladenets Reservoir; 34. Koprinka Reservoir; 35. Asenovets Reservoir.

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The sampling process included the following work steps: 1. Measurement of transparency; 2. Determination of the depth of euphoric zone; 3. Determination of the depth of sampling; 4. Collection of phytoplankton samples from the respective horizons with batometer and plankton net; 5. Mix the samples and receiving a mixed phytoplankton sample.

Each mixed phytoplankton sample was separated in three subsamples: sample for quantitative analysis, sample for qualitative analysis and non-fixed living sample. Qualitative samples with volume of 0.5 L have been used to determine the taxonomic composition of the phytoplankton. Samples, collected by filtration of a larger volume of water were added to the first one. Samples were fixed with 4% formalin.

The physicochemical parameters (temperature, oxygen saturation, pH and conductivity) in the water basins were measured *in situ* with calibrated field devices. Additionally, NH₄N, NO₂N, NO₃N, PO₄P, total phosphorus and nitrogen were analyzed by using a NOVA 60 spectrophotometer (MERCK) following adopted standards: ammonium nitrogen (ISO 7150/1), nitrite and nitrate nitrogen (EN 26777 and ISO 7890-1), total nitrogen (EN ISO 11905-1), phosphate phosphorus (EN ISO 6878) and total phosphorus (EN ISO 6878).

The taxonomic composition was determined by using a light microscope MAGNUM-T, with 10x40 magnification, equipped with 3Mpx digital camera and the guide of John et al. (2003), Komárek & Anagnostidis (2005), Stoyneva & Temniskova-Topalova (2007), Komárek et al. (2014).

The frequency quotient (FQ) was calculated for each taxon (Temniskova & Stoyneva, 2011).

Results and Discussion

The ecological analysis of the species includes distribution of the identified species and information about their habitats in Bulgaria. The physicochemical parameters of the water basins are presented in Table 1.

We have identified the following species from order Synechococcales, Spirulinales and Oscillatoriales (Figure 2).

Order Synechococcales

Family Pseudanabaenaceae

Genus *Jaaginema* ANAGNOSTIDIS ET KOMÁREK 1988

♦ *Jaaginema gracile* (BÖCHER) ANAGNOSTIDIS ET KOMÁREK 1988 [Syn.: *Oscillatoria gracilis* BÖCHER] (Figure 2.1). *Distribution in Bulgaria*: Small and medium-size

lowland reservoirs in Pontic province (L16). In the current study it was found and documented in Kamenets Reservoir.

Genus *Limnothrix* MEFFERT 1988

♦ *Limnothrix planctonica* (WOLOSZYNSKA) MEFFERT 1988 [Syn.: *Oscillatoria planctonica* WOLOSZYNSKA] (Figure 2.2). *Distribution in Bulgaria*: Black Sea freshwater coastal lakes; small and medium-size lowland reservoirs in Pontic province (L7, L16). In the current study it was found and documented in Durankulak swamp and Acheloy Reservoir.

♦ *Limnothrix redekei* (VAN GOOR) MEFFERT 1988 [Syn.: *Oscillatoria redekei* VAN GOOR] (Figure 2.3). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province; small and medium-size lowland reservoirs in Pontic province (L12, L16). In the current study it was found and documented in Drenovets, Kruchovitsa, Kamenets, Acheloy, Poroy and Yasna polyana Reservoirs.

Genus *Pseudanabaena* LAUTERBORN 1915

♦ *Pseudanabaena catenata* LAUTERBORN 1915 (Figure 2.4). *Distribution in Bulgaria*: Large deep reservoirs; small and medium-size semi-mountain reservoirs in Pontic province; small and medium-size semi-mountain reservoirs in Eastern Balkans; small and medium-size lowland reservoirs in Pontic province (L11, L12, L13, L16). In the current study it was found and documented in Enitsa, Telish, Valchovets, Kamenets, Kavatsite, Boika, Baniska, Daskal Atanasovo, Asenovets and Studen kladenets Reservoirs.

♦ *Pseudanabaena galeata* BÖCHER 1949 (Figure 2.5). *Distribution in Bulgaria*: Small and medium-size lowland reservoirs in Pontic province (L16). In the current study it was found and documented in Poroy Reservoir.

♦ *Pseudanabaena limnetica* (LEMMERMANN) KOMÁREK 1974 [Syn.: *Oscillatoria limnetica* LEMMERMANN] (Figure 2.6). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Eastern Balkans; small and medium-size lowland reservoirs in Pontic province (L13, L16). In the current study it was found and documented in Boika, Acheloy and Poroy Reservoirs.

♦ *Pseudanabaena mucicola* (NAUMANN ET HUBER-PESTALOZZI) SCHWABE 1964 (Figure 2.7). *Distribution in Bulgaria*: Large deep reservoirs; large lowland reservoirs with medium depth in Pontic province (L11, L14). In the current study it was found and documented in Ogosta and Koprinka Reservoirs.

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♦ *Pseudanabaena tenuis* KOPPE 1924 (Figure 2.8).
Distribution in Bulgaria: Large lowland reservoirs with medium depth in Pontic province (L14). In the current study it was found and documented in Ogosta Reservoir.

♦ *Pseudanabaena westiana* ANAGNOSTIDIS 2001 (Figure 2.9). *Distribution in Bulgaria:* Large deep reservoirs (L11). In the current study it was found and documented in Al. Stambolijski Reservoir.

Table 1. Physicochemical parameters of the investigated water basins.

Standing water basins	t (C°)	O ₂ (%)	pH	ε	NH ₄ N	NO ₂ N	NO ₃ N	PO ₄ P	Total P	Total N
Acheloy Reservoir	19.7	48.3	8.88	445	0.034	0.004	0.28	0.044	0.047	1.0
Al. Stambolijski Reservoir**	21.7	76.6	8.35	265.7	0.03	0.003	<0.20	0.012	0.024	<0.5
Aleru Lake	18.5	63.1	8.48	1864	0.066	0.007	0.2	<0.01	0.055	0.80
Asenovets Reservoir	16.9	67	8.1	368	0.019	0.003	<0.20	<0.010	<0.010	<0.5
Asparuchov val Reservoir	20.1	80.0	8.85	1044	0.057	0.009	0.30	<0.010	0.056	1.70
Baniska Reservoir	19.1	121.4	8.1	423	0.04	0.004	<0.20	<0.010	0.086	<0.50
Barsina Reservoir	19.9	214	8.86	654	0.219	0.067	0.81	0.027	0.148	4.1
Bistraka Lake	13.8	59.9	7.65	567	0.108	0.058	<0.20	0.021	0.147	1.10
Boika Reservoir	19.1	121.4	8.1	423	0.04	0.004	<0.20	<0.010	0.086	<0.5
Daskal Atanasovo Reservoir	26.6	92	8.3	568	0.151	0.006	<0.20	0.013	0.202	1.0
Drenovets Reservoir	23.1	97	8.5	345	0.03	0.004	0.22	0.039	0.049	0.9
Durankulak Swamp**	23.6	28.9	8.82	1210	0.042	0.021	<0.20	0.039	0.129	0.5
Enitsa Reservoir	9.2	44	8.02	522	1.55	0.052	0.16	0.009	0.187	2.1
Gyorgiysko Lake*	12.06	91.06	7.77	22	<0.010	0.003	<0.200	<0.010	<0.010	<0.5
Kamenets Reservoir	20.8	123.3	9.17	780	0.39	0.02	<0.20	<0.010	0.116	2.84
Kavatsite Reservoir	18.9	57.8	8.13	402	0.084	0.017	<0.20	<0.010	0.052	<0.5
Koprinka Reservoir**	25.1	80	9.4	195	0.026	0.005	0.89	0.026	0.032	1.10
Kovachitsa Reservoir	20.5	71	8.95	813	0.072	0.002	0.2	0.023	0.061	1.20
Kruchovitsa Reservoir	11.1	111	9.29	609	0.054	0.013	0.2	0.023	0.112	0.80
Kula Reservoir	12.2	75	8.43	414	0.043	0.013	<0.20	<0.010	0.018	<0.5
Lomtsi Reservoir	18.5	42.3	8.4	698	0.008	0.008	<0.20	0.118	0.334	<0.5
Ogosta Reservoir	12.4	66	8.13	201	<0.010	0.002	0.08	0.023	0.029	<0.5
Ovchi kladenets Reservoir	27.9	95	9.5	690	0.05	0.006	<0.20	<0.010	0.082	1.6
Pomorijsko Lake**	18.4	52.3	8.42	64000	0.17	0.025	0.6	0.023	0.07	3.0
Poroy Reservoir	20.5	61.6	8.73	690	0.093	0.02	<0.20	0.017	0.044	0.9
Rabisha Reservoir	19.9	85.5	8	202	0.019	0.002	0.23	<0.010	0.017	<0.5
Rasovo Reservoir	20.6	113	8.75	822	0.09	0.002	0.36	<0.010	0.218	2.10
Redzhepsko Lake*	5.5	74	7.19	14.3	<0.01	0.002	<0.20	<0.01	<0.01	<0.50
Shabla Lake**	25.7	105.2	8.42	847	0.11	0.02	<0.20	0.051	0.125	0.6
Studen kladenets Reservoir	25.2	109	8.5	253	0.092	0.002	<0.20	<0.010	0.029	1.9
Telish Reservoir	11.4	79	8.47	241	0.048	0.005	<0.20	0.007	0.054	<0.5
Valchovets Reservoir	10.2	70	8.96	516	0.334	0.016	<0.20	0.039	0.078	0.9
Yasna polyana Reservoir	21.8	79.4	8.34	291.7	0.04	<0.002	<0.20	<0.010	0.025	<0.5
Yastrebinovo Reservoir	17.8	73.4	7.92	343.7	0.031	0.006	<0.20	<0.010	0.029	0.60
Yovkovtsi Reservoir	19.2	92	8.24	225	0.012	0.006	<0.20	<0.01	0.022	<0.5

Legend: * - Located in National Park territory; ** - Located in Protected area according to NATURA 2000.

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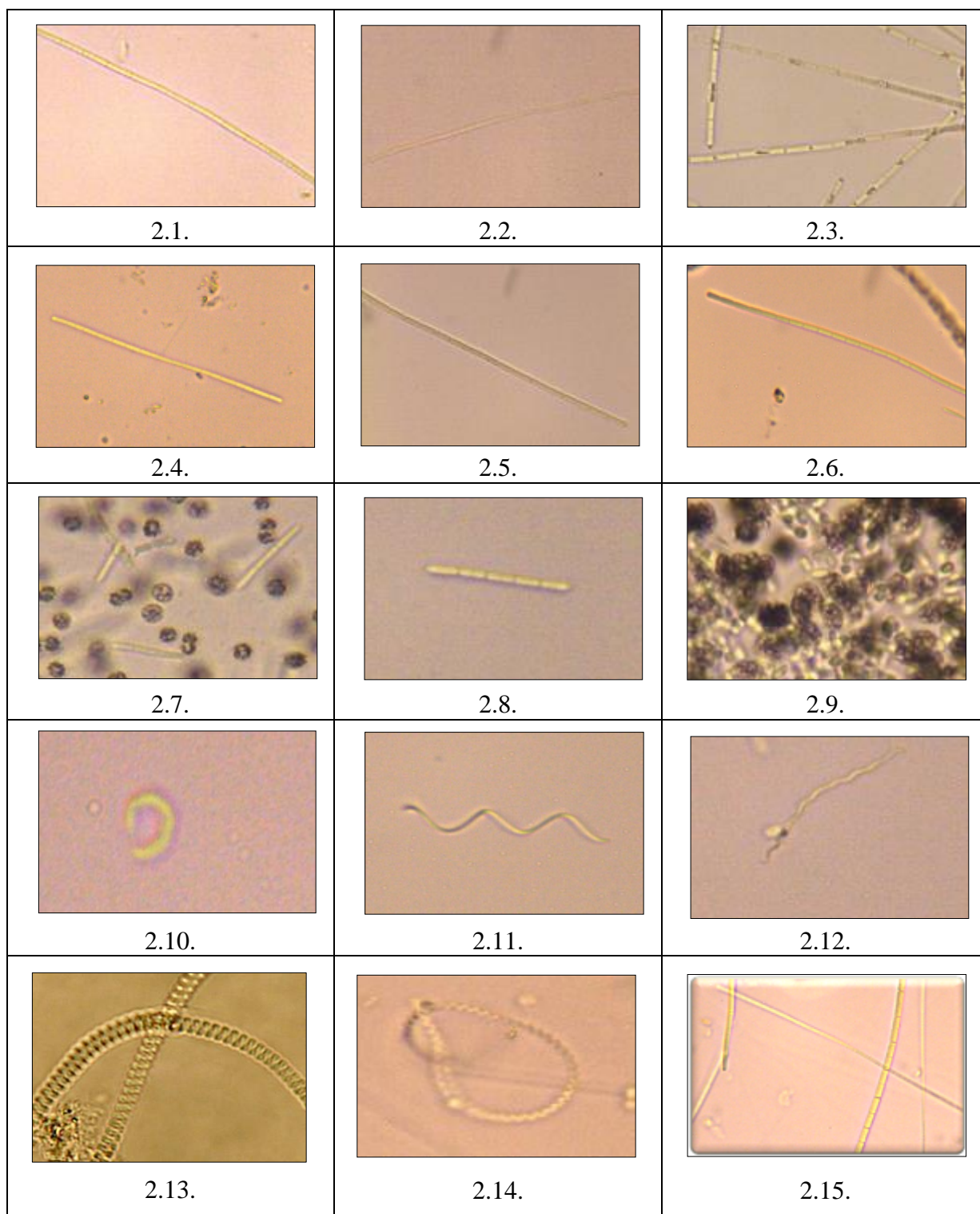


Figure 2. Microphotos of established cyanoprokaryotes: 2.1. *Jaaginema gracile*; 2.2. *Limnothrix planctonica*; 2.3. *L. redekei*; 2.4. *Pseudanabaena catenata*; 2.5. *P. galeata*; 2.6. *P. limnetica*; 2.7. *P. mucicola*; 2.8. *P. tenuis*; 2.9. *P. westiana*; 2.10. *Romeria chlorina*; 2.11. *Glaucospira laxissima*; 2.12. *Spirulina corakiana*; 2.13. *S. major*; 2.14. *S. subtilissima*; 2.15. *Geitlerinema amphibium*.

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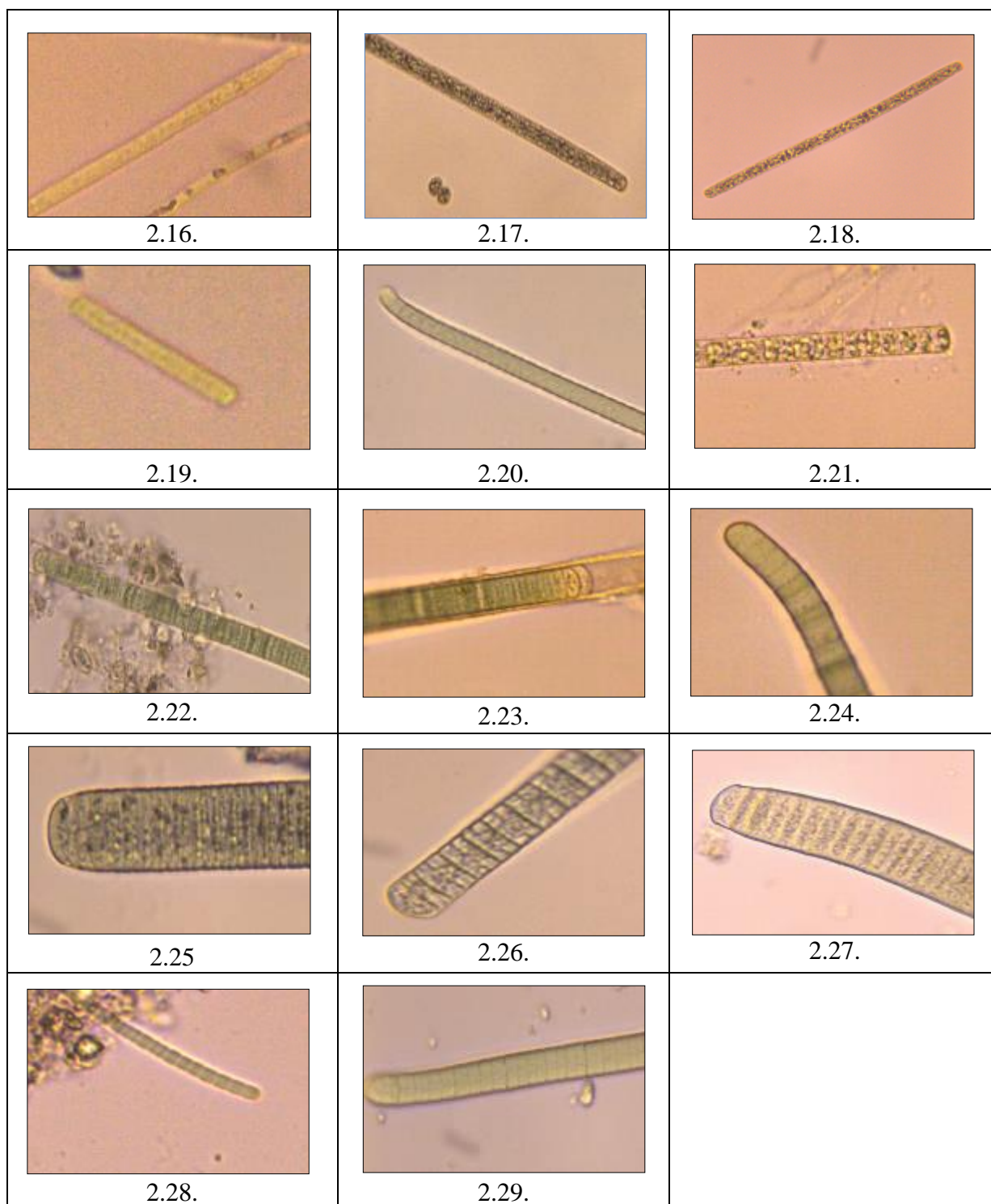


Figure 2. Microphotos of established cyanoprokaryotes: 2.16. *Microcoleus amoenus*; 2.17. *Planktothrix agardhii*; 2.18. *Planktothrix isothrix*; 2.19. *Phormidium bulgaricum*; 2.20. *Ph. chalybeum*; 2.21. *Ph. irriguum*; 2.22. *Lyngbya aestuarii*; 2.23. *Lyngbya hieronymusii*; 2.24. *Oscillatoria annae*; 2.25. *O. dzeman-sor*; 2.26. *O. limosa*; 2.27. *O. margaritifera*; 2.28. *O. spirulinoides*; 2.29. *O. tenuis*.

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Family Romeriaceae

Genus *Romeria* KOCZWARA IN GEITLER 1932

♦ *Romeria chlorina* BÖCHER 1949 (Figure 2.10). *Distribution in Bulgaria*: High mountain glacial lakes (L1). In the current study it was found and documented in Gyorgiysko Lake.

Order Spirulinales**Family Spirulinaceae**

Genus *Glaucospira*

♦ *Glaucospira laxissima* (G.S. WEST) (*Spirulina laxissima* G.S. WEST 1907) (Figure 2.11). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province; small and medium-size semi-mountain reservoirs in Eastern Balkans; small and medium-size lowland reservoirs in Pontic province (L12, L13, L16). In the current study it was found and documented in Drenovets, Rasovo, Kovachitsa, Kamenets, Boika and Baniska Reservoirs.

Genus *Spirulina* TURPIN EX GOMONT 1892

♦ *Spirulina corakiana* PLAYFAIR 1914 (Figure 2.12). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province (L12). In the current study it was found and documented in Yasna polyana Reservoir.

♦ *Spirulina major* KÜTZING EX GOMONT 1892. (Figure 2.13). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province (L12). In the current study it was found and documented in Daskal Atanasovo Reservoir.

♦ *Spirulina subtilissima* KÜTZING EX GOMONT 1892 (Figure 2.14). *Distribution in Bulgaria*: Small and medium-size lowland reservoirs in Pontic province (L16). In the current study it was found and documented in Kruchovitsa Reservoir.

Order Oscillatoriales**Family Coleofasciculaceae**

Genus *Geitlerinema* (ANAGNOSTIDIS ET KOMÁREK) ANAGNOSTIDIS ET KOMÁREK 1989

♦ *Geitlerinema amphibium* (AGARDH EX GOMONT) ANAGNOSTIDIS 1989 [Syn.: *Oscillatoria amphibia* AGARDH EX GOMONT] (Figure 2.15). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province (L12). In the current study it was found and documented in Baniska Reservoir.

Family Microcoleaceae

Genus *Microcoleus* DESMAZICRES EX GOMONT 1892

♦ *Microcoleus amoenus* (Gomont) (*Phormidium amoenum* KÜTZING 1843 EX ANAGNOSTIDIS ET KOMÁREK 1988) [Syn.: *Oscillatoria amoena* GOMONT] (Figure 2.16). *Distribution in Bulgaria*: Small and medium-size lowland reservoirs in Pontic province (L16). In the current study it was found and documented in *Acheloy Reservoir*.

Genus *Planktothrix* ANAGNOSTIDIS ET KOMÁREK 1988

♦ *Planktothrix agardhii* (GOMONT) ANAGNOSTIDIS ET KOMÁREK 1988 [Syn.: *Oscillatoria agardhii* GOMONT] (Figure 2.17). *Distribution in Bulgaria*: Lowland or semi-mountain natural lakes end swamps in Pontic province; riverine wetlands in ecoregion Eastern Balkans; small and medium-size semi-mountain reservoirs in Pontic province; small and medium-size lowland reservoirs in Pontic province (L4, L6, L12, L16). In the current study it was found and documented in Rabisha, Rasovo, Barsina, Enitsa, Kruchovitsa, Telish, Kamenets, Yastrebino, Lomtsi, *Acheloy Reservoirs* and Bistraka Lake.

♦ *Planktothrix isothrix* (SKUJA) KOMÁREK ET KOMÁRKOVÁ 2004 [Syn.: *Oscillatoria mougeotii* BORY EX GOMONT] (Figure 2.18). *Distribution in Bulgaria*: Black Sea oligohaline coastal lakes; large deep reservoirs; small and medium-size semi-mountain reservoirs in Pontic province (L8, L11, L12). In the current study it was found and documented in Daskal Atanasovo and Ovchi kladenets Reservoirs and Aleru Lake.

Family Oscillatoriaceae

Genus *Phormidium* KÜTZING EX GOMONT 1892

♦ *Phormidium bulgaricum* (KOMÁREK) ANAGNOSTIDIS ET KOMÁREK 1988 [Syn.: *Oscillatoria bulgarica* KOMÁREK] (Figure 2.19). *Distribution in Bulgaria*: Black Sea euhaline and hyperhaline coastal lakes (L10). In the current study it was found and documented in Pomorijsko Lake.

♦ *Phormidium chalybeum* (MERTENS EX GOMONT) ANAGNOSTIDIS ET KOMÁREK 1988 [Syn.: *Oscillatoria chalybea* MERTENS EX GOMONT] (Figure 2.20). *Distribution in Bulgaria*: Small and medium-size semi-mountain reservoirs in Pontic province (L12). In the current study it was found and documented in Kula Reservoir.

♦ *Phormidium irriguum* (KÜTZING EX GOMONT) ANAGNOSTIDIS ET KOMÁREK 1988 [Syn.: *Oscillatoria irrigua* KÜTZING EX GOMONT] (Figure 2.21). *Distribution in Bulgaria*: High mountain glacial lakes (L1).

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In the current study it was found and documented in Redzhepsko Lake.

Genus *Lyngbya* C. AGARDH EX GOMONT 1892

♦ *Lyngbya aestuarii* LIEBMAN EX GOMONT 1892 (Figure 2.22). *Distribution in Bulgaria*: Black Sea euhaline and hyperhaline coastal lakes (L10). In the current study it was found and documented in Pomorijsko Lake.

Genus *Limnographis* KOMÁREK ET AL., 2013

♦ *Limnographis hieronymusii* LEMMERMANN 1905 (*Lyngbya hieronymusii* LEMMERMANN 1905) (Figure 2.23). *Distribution in Bulgaria*: Large deep reservoirs (L11). In the current study it was found and documented in Studen kladenets Reservoir.

Genus *Oscillatoria* VAUCHER EX GOMONT 1892

♦ *Oscillatoria annae* VAN GOOR 1918 (Figure 2.24). *Distribution in Bulgaria*: Large deep reservoirs (L11). In the current study it was found and documented in Studen kladenets Reservoir.

♦ *Oscillatoria dzeman-sor* WORONICHIN IN WORONICHIN ET CHACHINA 1929 (Figure 2.25). *Distribution in Bulgaria*: Mountain lakes in ecoregion Pontic province (L2). In the current study it was found and documented in Yovkovtsi Reservoir.

♦ *Oscillatoria limosa* AGARDH EX GOMONT 1892 (Figure 2.26). *Distribution in Bulgaria*: Mountain lakes in ecoregion Pontic province; Black Sea euhaline and hyperhaline coastal lakes (L2, L10). In the current study it was found and documented in Yovkovtsi Reservoir and Pomorijsko Lake.

♦ *Oscillatoria margaritifera* KÜTZING EX GOMONT 1892 (Figure 2.27). *Distribution in Bulgaria*: Black Sea freshwater coastal lakes; Black Sea euhaline and hyperhaline coastal lakes (L7, L10). In the current study it was found and documented in Shabla and Pomorijsko Lakes.

♦ *Oscillatoria spirulinoides* WORONICHIN 1932) (Figure 2.28). *Distribution in Bulgaria*: Black Sea freshwater coastal lakes (L7). In the current study it was found and documented in Shabla Lake.

♦ *Oscillatoria tenuis* AGARDH EX GOMONT 1892 (Figure 2.29). *Distribution in Bulgaria*: Mountain lakes in ecoregion Pontic province; Black Sea freshwater coastal lakes; small and medium-size lowland reservoirs in Pontic province (L2, L7, L16). In the current study it was found and documented in Asparuchov val and Yovkovtsi Reservoirs and Shabla Lake.

It was found that the described filamentous cyanoprokaryotes of the order **Synechococcales** belong to two families. Family Pseudanabaenaceae is represented by three genera - *Pseudanabaena*, *Limnothrix*, and *Jaaginema*. The genus *Pseudanabaena* was the most widespread. The genus *Jaaginema* have very low frequency. The genus *Pseudanabaena* was represented by the following species: *Pseudanabaena catenata*, *Pseudanabaena galeata*, *Pseudanabaena limnetica*, *Pseudanabaena mucicola*, *Pseudanabaena tenuis* and *Pseudanabaena westiana*. The most common species is *Pseudanabaena catenata* (FQ=32). The species *Limnothrix redekei* (FQ=18) and *Limnothrix planctonica* (FQ=6) belong to genus *Limnothrix*. Genus *Jaaginema* was represented with a single species - *Jaaginema gracile*. Family Romeriaceae is represented by genus *Romeria* with the species *Romeria chlorina* (FQ=3).

Order **Spiroinales** was represented with two genera – *Spirulina* and *Glaucospira*, which belong to family Spirulinaceae. Genus *Spirulina* has the highest FQ of the family. This genus includes *Spirulina corakiana*, *Spirulina major* and *Spirulina subtilissima*. All species from the genus have low frequency (FQ=3). Genus *Glaucospira* was represented only with one species - *Glaucospira laxissima* (FQ=18).

It was found that the described filamentous cyanoprokaryotes of the order **Oscillatoriales** belong to three families - Coleofasciculaceae, Microcoleaceae and Oscillatoriaceae. Family Coleofasciculaceae contain genus *Geitlerinema* with the species *Geitlerinema amphibium*. Family Microcoleaceae is represented by two genera – *Microcoleus* and *Planktothrix*. Genus *Planktothrix* is represented by two species - *Planktothrix agardhii* and *Planktothrix isothrix*, as the first one is more common (FQ=34). Family Oscillatoriaceae is represented by four genera - *Phormidium*, *Lyngbya*, *Limnographis* and *Oscillatoria*. The predominant genus was *Oscillatoria*. Six species (*Oscillatoria annae*, *Oscillatoria dzeman-sor*, *Oscillatoria limosa*, *Oscillatoria margaritifera*, *Oscillatoria spirulinoides* and *Oscillatoria tenuis*) were identified as *Oscillatoria*. The genus *Phormidium* includes several species – *Phormidium bulgaricum*, *Phormidium chalybeum*, *Phormidium irriguum* and *Phormidium amoenum*. Genus *Lyngbya* is represented by *Lyngbya aestuarii* (FQ=3). Genus *Limnographis* was represented by *Limnographis hieronymusii* (FQ=3).

The frequency quotient (FQ, %) of the species is presented in Figure 3.

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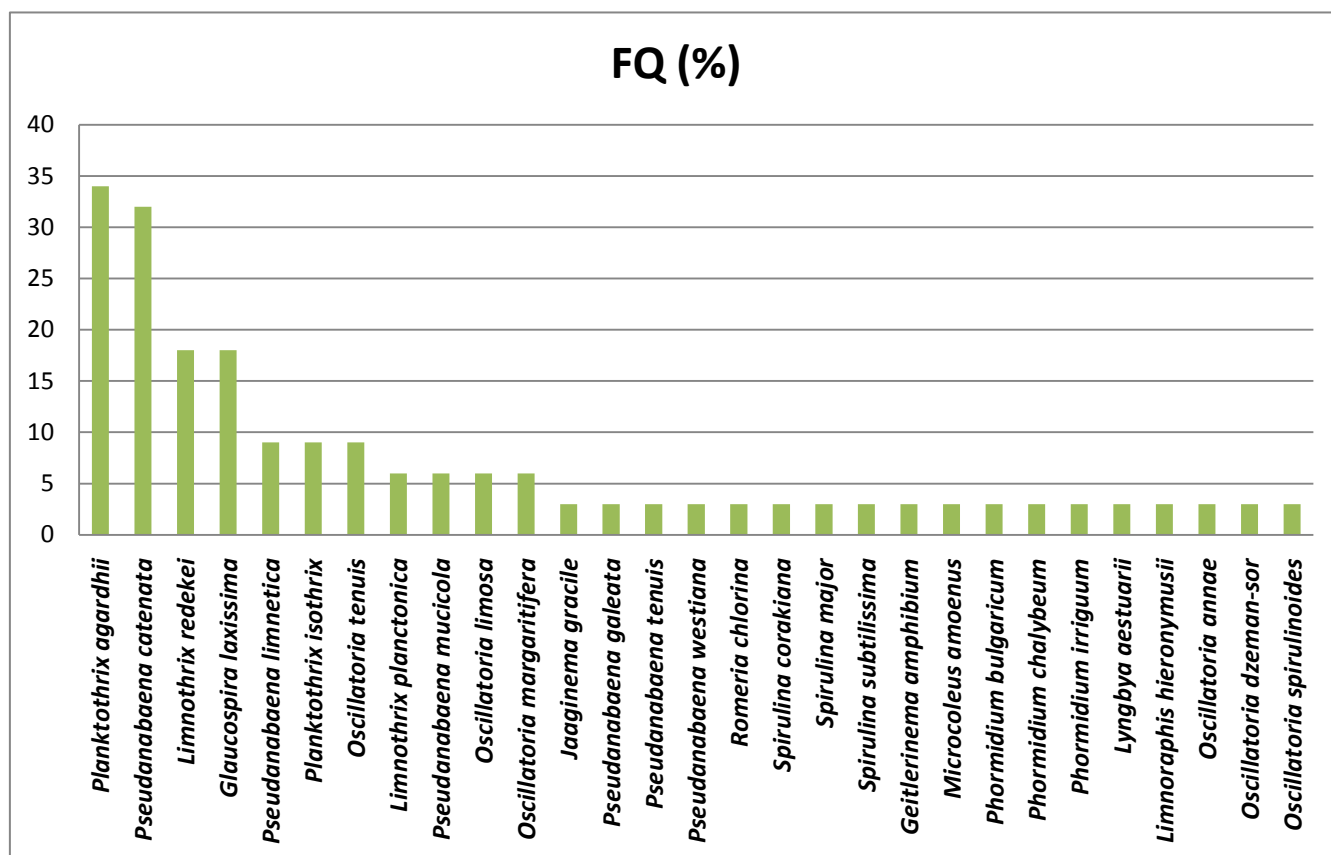


Figure 3. Frequency quotient of the established cyanoprokaryotic species from orders Synechococcales, Spirulinales and Oscillatoriales in Bulgarian standing water basins.

The species *Limnothrix planctonica*, *Pseudanabaena mucicola*, *Pseudanabaena westiana*, *Romeria chlorina*, *Phormidium bulgaricum*, *Phormidium irriguum* and *Lyngbya aestuarii* were found in water basins, which are included in protected territories. Thus, this study fulfills one of the 10 directions of the Bulgarian algological studies, suggested by Temniskova et al. (2005).

With the established in the current study 29 species that belong to 13 genera from the orders Oscillatoriales, Spirulinales and Synechococcales, we enrich the existing information about the distribution of the filamentous cyanoprokaryotes in the standing waters in Bulgaria.

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