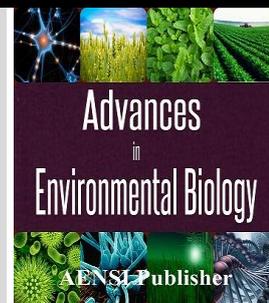




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Diversity of Cyanobacteria from Yamchi dam, Ardabil- Northwest of Iran

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ABSTRACT

Cyanobacteria species of Yamchia reservoir of drinking and irrigation water of Ardabil Province (northwest Iran) was studied from October 2013 to November 2014. In this paper a review of identified species are presented. A total of 16 species belonging to 11 Genera, 9 Families and 4 Orders were identified, from which 10 species are planktic. *Microcystisaeruginosa* and *Aphanizomenonflosaquaewere* most abundant species in surface water during summer months, mainly due to regulating their buoyancy via gas vesicles. In general *Oscillatoria* is the most dominant Genus in the region with 4 species including *Oscillatoriacurviceps*, *Oscillatorialimos*, *Oscillatoriaprinceps* and *Oscillatoriatenuis*.

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INTRODUCTION

Cyanobacteria have acquired remarkable adaptations to the most diverse aquatic and terrestrial environments during evolution. Probably owing to their physiological flexibility and long evolutionary history, Cyanobacteria inhabit a large variety of terrestrial and aquatic habitats from deserts to lakes as well as hot springs and glaciers [7]. Cyanobacteria form biofilms (Microbial mats) on shores and on the surface of stones, plants and artificial objects [15]. Planktic Cyanobacteria inhabit diverse aquatic environment from Antarctic lakes and nutrient-poor oceans to highly nutrient-rich lakes and ponds. They possess gas vacuoles, allowing buoyancy and facilitating the formation of blooms [16]. Many species of Cyanobacteria are well known as bloom formers and toxin producers in freshwaters all over the world, which are harmful to public health and environment [1]. Many papers dealing with Cyanobacterial diversity in different regions and habitats, e.g. Anna, *et al.*, Hamed, A.F. [2], Patil and Nandan, Rai and Misra, Hasler *et al.*, Hauer, T. [4]. A few studies have been made on the Cyanophytes in Iran [14,5].

Due to the problems brought by Cyanobacterial blooms, the present paper aims to contribute to the knowledge of Cyanobacterial diversity in Iran through examining the cyanobacteria species of Yamchi dam which is the main resource for drinking and irrigation purposes in the region. Algal diversity of the region has not been studied before and the present study is the first recording on cyanobacteria of this region.

MATERIAL AND METHODS

The Yamchi dam is located between 38° 4' N and 48°5' E, in 25 km southwest of Ardabil city (Ardabil province, northwest of Iran) and 5 km northeast of Nir city. The main source of Yamchi dam is Balikhli River which originates from Bozgoosh and Sabalan elevations in northwest Iran. Several important tributaries including BorjlouChay, SaghhezchiChay, AghlaghanChay, JurabChay ... in their way downhill join the BalikhliChay and increase its water volume. It also receives huge amount of various waste water with domestic, industrial and agricultural origins. The length of Yamchidam lake is about 3 km and depth in deepest point is 15-25 m. The mean annual rainfall in the region is 385 mm and mean annual temperature is 8.8 °C.

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Benthic and Planktic samples were taken from Yamchi reservoir and its downstream and upstream on Balikhli River according to Bellinger and Sige. The samples were collected at monthly intervals from October 2013 to November 2014. They were preserved with 4% formalin solution. The samples were identified using photomicroscope. Traditional taxonomic criteria based on the morphological characteristics were used for identification [10,6].

RESULTS AND DISCUSSION

In total 16 species belonging to 11 Genera and 9 Families and 4 Orders were identified. The identified species were systematically arranged as follow:

Class-Cyanophyceae Scha:

- 1) Order- Chroococcales Wett.
- a) Family- Chroococcaceae

Chroococcus Nageli:

Colony of few cells are surrounded by mucilaginous envelopes, more or less spherical, cells rarely spherical, usually hemispherical to irregular, with homogeneous or granular content. Pale blue- green, yellowish or so. Diagnostic features are related to habitat, cell dimension and number in colony, sheath features.

Chroococcus limneticus Lemmermann:

Cells 5-7 μm wide, homogeneous or granular, blue-green; Sheath broad, homogeneous; colonies up to 16-celled, planktonic.

Habitat: Planktic, Yamchi dam.

Gloeocapsopsis Geitler ex Komarek:

Cells are usually aggregated in irregular, microscopic colonies. Cells are subspherical or irregular- rounded, usually have individual gelatinous envelopes. Colonies are surrounded by thin, firm and often colored sheaths. Cell content is pale or bright blue-green.

Gloeocapsopsis crepidinum (Turet) Geitler ex Komarek:

Cells usually in regular colonies mostly 2-16 celled to many-celled. Cells blue- green. Envelopes colorless, thin, firm, following the cell outline.

Habitat: Epilithic, downstream of dam on Balikhli River.

- b) Family- Microcystaceae Elenkin.

Microcystis Kutzing ex Lemmermann:

This genus has irregular micro- or macroscopic colonies that are free-floating, compact or clathrate may be composed of clustered subcolonies and has sparsely or densely, irregularly arranged cells. The mucilage is fine, colorless, sometimes forming a wide margin around the cells. Cells are spherical or hemispherical after division and pale blue-green, but they appear brownish due to aerotopes that mask the blue-green color of the protoplast. Main diagnostic characters are: form of colony, cells dimension and density

Microcystis aeruginosa (Kutzing) Kutzing:

An ovate, Spherical or irregularly lobed, saccate and clathrate colony of numerous spherical cells, densely aggregated within a hyaline gelatinous matrix. Cell contents blue-green, highly granular and with conspicuous pseudovacuoles. Cells 3-4.5 μm in diameter (Fig. 1 and 2).

Habitat: Planktic, Yamchi dam abundant in summer months.

- c) Family- Spirulinaceae

Spirulina Turpin ex Gomont:

Trichomes are cylindrical, screwlike coiled, solitary or forming fine, mucilaginous mats. Regular coiling occurs in all species, but ranges from loosely to tightly screwlike or helical, coils may be compressed or may have spaces between them. Terminal cells are usually not attenuated. Apical cells rounded. Most important diagnostic characters for species delineation are: the distance between spirals, width of trichome and spirals.

Spirulina gigantea Schmidle:

Trichomes cylindrical, screw like, regularly coiled, solitary. Cells not constricted at scarcely visible cell walls. Bright blue green. Trichome 2.5 μm wide, spirals 10-12.5 μm wide, distance between the spirals 7-12.5 μm (Fig. 4).

Habitat: Planktic and benthic, Yamchi dam, Balikhli River.

1) Order- Nostocales Cavalier-Smith

Family- NostocaceaeEichler

Anabaena Bory ex Bornet&Flahault:

Filamentous, filaments solitary or in free clusters. Trichomes are straight, curved or regularly coiled. Always without firm sheaths, but sometimes with mucilaginous, hyaline, colorless envelopes. Trichomes are constricted or unconstructed at the cross walls, uniseriate, isopolar. Cells are spherical, ellipsoidal, sometimes bent, pale to bright blue-green or yellow-green, the planktic species have aerotopes. Heterocytes are intercalary, solitary, up to nine per filament. Akinetes are spherical, ellipsoidal, cylindrical, curved, intercalary, solitary or in groups of two to five, in some species adjacent to heterocytes. Species delineation is related to: habitat, trichome shape, shape and dimension of vegetative cells, heterocytes and akinetes, shape of terminal cell, location and distance between akinetes and heterocytes.

Anabaena flos-aquae(Lyngb.)Brebisson:

Trichomes planktonic, very flexuous, solitary. Cells spherical or nearly so, 4-6 μm wide, 6-8 μm long, cell contents granular with conspicuous pseudovacuoles. Heterocysts spherical 5-9 μm in diameter. Akinetes cylindrical, often curved, solitary or in series, usually adjacent to heterocysts, 6-12 μm in diameter, 20-30 μm long (Fig. 3).
Habitat: Planktic, Yamchi dam.

Aphanizomenon Morren ex Bornet&Flahault:

Filamentous, free-floating, solitary, in few species joined into fascicle-like microscopic or macroscopic colonies, trichomes straight, isopolar, slightly curved, cylindrical or narrowing toward ends, with or without constrictions at cross walls. Cells are cylindrical or barrel shaped, pale blue-green with aerotopes. Heterocytes are almost spherical, ellipsoidal or cylindrical with two pores, always intercalary and solitary. Akinetes are long or short cylindrical with rounded ends or elliptical, adjacent to heterocytes or distant. Diagnostic characters are mostly as follow: Form and dimension of trichome, akinetes, position of akinetes, form of terminal cells.

*Aphanizomenon flosaquae*Ralfs ex Bornet&Flahault:

Trichomes straight or somewhat curved, usually without sheaths, sometimes constricted at the cross walls and slightly attenuate. Cells cylindrical, 4-6 μm diameter and 6-12 μm long. Heterocysts cylindrical, intercalary, 5-7 μm in diameter and 7-20 μm long, akinetes elongate, cylindrical, solitary formed near the middle of the trichome but not adjacent to the heterocyst, 6-8 μm in diameter and 20-60 μm long (Fig. 5,6).

Habitat: Planktic, Yamchi dam.

2) Order- Oscillatoriales Cavalier-Smith

a) Family- AmmatoideaceaeElenkin

Homoeothrix(Thu. ex Bor. &Flaha.) Kirchner:

Filaments are solitary or forming mats, simple not branched or very rarely laterally branched (false branching), erect, solitary or in small loose fascicles attached to substrata basally. Sheaths are thin, firm, hyaline. Trichomes are thin, straight or coiled, cylindrical, constricted or not constricted at the cross walls, tapering at ends and sometimes elongated into thin, hyaline hairs. Bases of filaments of some species are enlarged; pale blue-green, olive green or grayish. Species delineation is related to colony form, trichome and cell dimension.

Homoeothrix janthina (Bornet&Flahault) Starmach:

Filaments in groups, nearly in a parallel arrangement, attached to the substrate, forming small green to black-green tufts, filaments erect or curved, unbranched, rarely ending in a fragile hair. Sheaths very thin, narrow, colorless. Trichomes 2 μm wide, cells typically isodiametric, pale grey blue to blue green, slightly constricted at the cross walls (Fig. 8).

Habitat: Epilithic, Balikhli River.

b) Family- OscillatoriaceaeEngler.

*Oscillatoria*Vaucher ex Gomont:

Very common genus consisting of unbranched filaments in plankton or attached forms. The thallus is usually flat, smooth. Trichomes are straight or curved, cylindrical. Sheaths are usually absent. Cells are short and discoid, not constricted or constricted at cross walls, without aerotopes but with fine granulation or with solitary granules. End cells rounded, sometimes capitates or with narrow calyptras. False branching, heterocytes and akinetes lacking. Diagnostic characters are: Trichome and cell dimension, presence/ absence of constriction, presence/ absence of granules, color, characteristics of terminal cell.

Oscillatoriacurviceps C.A. Agardh ex Gomont:

Trichome blue-green in color, nearly straight or slightly curved, both ends slightly tapered and slightly curved, without constriction at cross walls, cells short, 10-15 μm wide, 2-5 μm long, sometimes with granules along cross walls, terminal cells rounded (Fig. 7).

Habitat: Epilithic and in the form of algal mat on the substrate surface, Balikhli River.

Oscillatorialimosa C. Agardh ex Gomont:

Long trichomes, straight, brown, olive-green or blackish blue-green, solitary or nearly parallel arranged to form mats. Trichome not attenuated or very shortly, slightly attenuated at the ends. Apical cell round, the outer membrane thickened but without definite calyptras. Cells with content finely granulated, short, 12-18 μm wide, 3.5-5 μm long, not constricted at cross walls, which are usually granular. Rarely with thin, not lamellated, colorless sheath (Fig. 9).

Habitat: Benthic and in the form of algal mat on the substrate surface, Balikhli River.

Oscillatoriaprinceps Vaucher ex Gomont:

Trichomes long, solitary or loosely entangled to form small floating plant masses, which are black-green in color; trichomes straight or slightly curved, very slightly and briefly attenuated at the sometimes bent ends. Cells very short, Cells 35- 40 μm wide, 4-6 μm long, not constricted at cross walls, which are not granular, cell contents densely granular. Apical cell usually not capitates, sometimes very slightly so, sometimes with keritomized content, the outer membrane broadly convex and smooth (Fig. 10).

Habitat: Epilithic and in the form of algal mat on the substrate surface, Balikhli River.

Oscillatoriatenuis C.A. Agardh ex Gomont:

Trichomes bright blue-green, Straight or slightly flexuous. Apical cell convex, smooth and capitates, outer membrane sometimes slightly thickened. Cells 5-8 μm in diameter, 2-3.5 μm long, constricted at the cross walls, which are granular (Fig. 11).

Habitat: Planktic, epilithic and in the form of algal mat on the substrate surface, Balikhli River.

c) Family- Phormidiaceae Anagnostidis & Komarek

Tychonema Anagnostidis & Komarek

Trichomes are solitary or organized into fine mats, which may be benthic or planktonic. Trichomes are cylindrical, without sheaths or with fine facultative mucilaginous sheaths, without false branching, usually not constricted at the cross walls. Filaments are straight or occasionally slightly irregularly coiled or more or less curved, not attenuated at ends. Cells identical in morphology, cell content is pale and alveolar with keritomized chromatoplasma. Diagnostic characters: habitat, cell dimension, form of apical cell.

Tychonemabourrellyi (J.W.G. Lund) Anagnostidis & Komarek:

Description: Trichomes solitary, long, straight sometimes more or less curved, not attenuated at ends, not constricted at cross walls, without sheaths, pale olive green. Cells cylindrical, 4 μm wide and 5-9 μm long, without gas vesicles but with keritomized cytoplasm. Apical cells rounded (Fig. 13).

Habitat: Planktic, Yamchi dam.

d) Family- Pseudanabaenaceae Anagnostidis & Komarek

Planktolyngbya Anagnostidis & Komarek

Filaments are free living, solitary, free floating, straight, flexuous, wavy or irregularly coiled, with firm, thin, colorless sheaths and very rarely false branched. Trichomes are cylindrical, isopolar, uniseriate, unconstructed or slightly constricted at the cross walls, not attenuated toward ends, with rounded apical cells. Cells are cylindrical, usually longer than wide. Diagnostic characters: habitat, trichome shape, terminal cell.

Planktolyngbyalimnetica (Lemmermann) Komarkova-Legnrova & Cronberg:

Trichomes solitary with thin, simple, colorless but firm sheaths, straight or slightly curved, not attenuated at the ends, narrow, up to 2 μm wide, uniserial, cells longer than wide, not constricted at cross walls, without aerotopes, end cells rounded. Cell content pale blue-green, yellowish (Fig. 12).

Habitat: Planktic, Yamchi dam.

3) Order- Synechococcales

Family- Merismopediaceae Elenkin

Aphanocapsa Nageli:

Comprises microscopic to macroscopic, mucilaginous colonies with irregularly arranged cells of various densities that are spherical or irregular. Colonial mucilage is mainly homogenous and colorless. Cells have no

individual envelope or rarely have a fine surrounding slimy layer that is distinct from the common mucilage. Cells are spherical, but after division they are hemispherical, pale or bright blue-green or olive green with no gas vesicles.

Aphanocapsamuscicola(Meneghini) Wille:

Colony irregular or united into an amorphous mass, with colorless mucilage. Cells spherical, 2-4 μm (Fig. 14).

Habitat: Planktic, Yamchi dam.

*Merismopedia*Meyen:

This genus comprises flattened, free-living, platelike, more or less rectangular colonies that have one layer of cells, arranged loosely or densely in perpendicular rows and enveloped by fine, colorless, usually indistinct mucilage. Colonies are flat or slightly wavy, and sometimes composed of subcolonies. Cells are spherical or widely oval before division, pale or bright blue-green. Diagnostic features: colony type; color, dimension and other characteristics of cells.

*Merismopediakonvoluta*Brebisson *ex kutzing*:

Large colony of spherical or oblong cells, colony irregularly quadrangular, forming extensive sheets with convolute margins. Cells greenish or bluish yellow (Fig. 15).

Habitat: Planktic, Yamchi dam.

*Merismopediapunctata*Meyen:

Flat, quadrate colony, up to 64 cells, usually loosely arranged but in regular rows, Spherical, widely oval or hemispherical cells, sometimes in compact groups of 4-8 individuals; cells 2.5-4 μm wide, pale blue-green, cell contents homogenous (Fig. 16).

Habitat: Planktic, Yamchi dam. Scattered among other algae in lake.

From 16 species identified 6 species belonged to the order Oscillatoriales, 4 species to the order Chroococcales, 3 Species to the order Synechococcales and 2 species to the order Nostocales. Among the Families, Oscillatoriaceae was represented with 4 species and Merismopediaceae with 3 species is in the next order.

Oscillatoria with 4 species was the dominant genus in the region, *Merismopedia* with 2 species is in the next order and the rest of the genera were represented by single species. The use of freshwater algae as an indicator for the management of water resource is quite important. Fifteen species of blue-green algae have been reported as polluted water algae, and eight of them belong to the genus *Oscillatoria*. *Oscillatoria tenuis* and *O. limosa* have been reported by researchers more often than any other species as reliable indicators of organic pollution [8].

In total, 10 species of Cyanobacteria identified in the region, were filamentous and 6 species colonial. The recorded species belonged to the Planktons, Epilithes and cyanobacterial mats. The planktic species included 58.82% of the total number of species.

Among the species cited, *Microcystisaeruginosa*, *Aphanizomenon flosaquae*, and *Anabaena flos-aquae* are considered as bloom forming and potentially toxic cyanobacteria [10,12,17]. The temperature is considered to be an important factor in the periodicity of cyanobacteria especially for planktic species. *Microcystisaeruginosa* and *Aphanizomenon flosaquae* were abundant in surface water in summer months without forming any typical blooms and were not observed in spring and autumn. The buoyancy is regulated by gas vesicles. *Merismopedia* species have no special periodicity; this genus was found in all months and in different depths, also *Planktolyngbya*.

Microcystisaeruginosa is considered as toxic and bloom forming species all over the world [17]. The tendency to float high in the water results in the formation of large, macroscopic clots and floating crusts which develop as the plants push each other above the surface. Prescott [8] recorded that the occurrence of *Aphanizomenon flosaquae* is so consistently related to hard water lakes that it may be used as an index organism for high pH and usually a high nitrogen and carbonate content (especially when the plant appears as a water bloom). *Anabaena flos-aquae* was not dominant in the region.

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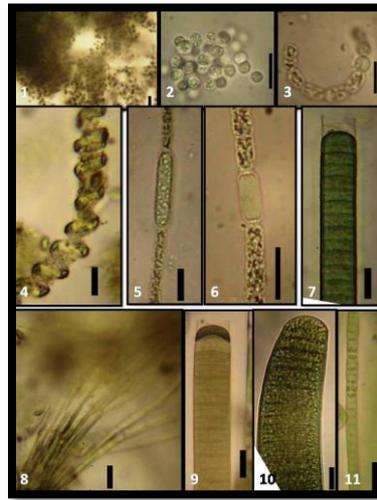


Fig. 1-11-1-2: *Microcystis aeruginosa*, 1.Colony, 2.Individual cells. 3. *Anabaena flosaqua*. 4. *Spirulina gigantea*. 5-6 *Aphanizomenon flosaqua*.5. Trichome with akinet in the midregion. 6. Trichome with heterocyte in the midregion. 7.*Oscillatoria curvipes*. 8.*Homoeothrix janthina*. 9. *Oscillatoria limosa*. 10. *Oscillatoria princeps*. 11. *Oscillatoria tenuis*. Bar= 10 μ m.Phtographer: JamilehPanahy.

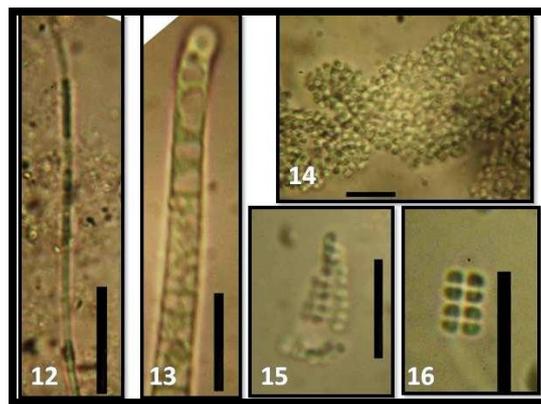


Fig. 12-16: 12.*Planktolyngbya limnetica*.13. *Tychonema bourrellyi*. 14.*Aphanocapsa muscicola*. 15. *Merismopedia convolute*. 16. *Merismopedia punctata*. Bar= 10 μ m.Phtographer: JamilehPanahy.

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