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Cyclotella iranica sp. nov. (Bacillariophyta: Coscinodiscophyceae), a new diatom from the Karaj River, Iran

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Abstract

Cyclotella iranica sp. nov. is described from the Karaj River, Iran. The morphology of *Cyclotella iranica* is documented with light and scanning electron micrographs and discussed in comparison with several related species: *Cyclotella fottii*, *C. delicatula*, *C. andancensis* var. *adnanensis*, *C. andancensis* var. *bauzilensis* and *C. andancensis* var. *bipolaira*. *Cyclotella iranica* shares with these related *Cyclotella* species the following features: unequal stria pattern, one sessile rimoportula and several marginal fultoportulae. It is distinguished from them by the position of central fultoportula(e), which is (are) situated at the central end of the striae. It is known only from the type locality; the autecology of *Cyclotella iranica* shows that it is tolerant of nutrient and organic enrichment.

Key words: *Cyclotella*, centric diatom, new species, Iran, Karaj River

Introduction

The Karaj River is one of the longest rivers of the Central Iranian Plateau (245 km; Bakhtiari 2008). Its water is used for agriculture, gardening and drinking by the residents of the Karaj River valley (and sub-catchments); it also meets the industrial and agricultural demands of the cities of Karaj, Tehran, Shahriar and Varamin (Rahmati 2007). This area of Iran is little studied for its diatom flora (Jamalou *et al.* 2007); the diatom flora of the Karaj River has not been investigated. The river suffers from heavy pollution due to unregulated releases of rural waste, primarily from the restaurants along the river and surrounding villages. Because of the Karaj River's primary importance to the province of Tehran, this study was undertaken to explore the diatom diversity of the river and to evaluate the relationship of the diatom communities to water quality.

The river starts in the north-western region of the plateau on the southern slope of the Albourz range. Its main tributaries are Welayat Rud, located in the north of Tehran, and Warange Rud beginning in the central Albourz ranges and located in the north-west of Karaj. These streams join at Gachsar to form the Karaj River. The catchment area of the Karaj River is 840 km^2. This terrain is delimited to the north by the central Albourz mountain ranges, the south by the city of Karaj, the east by the mountainous terrain of Tehran, and the west by the north end of Karaj (Rahmati 2007).

Epipelic samples were taken from the margins of the river monthly from March 2011 to April 2012. During this research, a new species of *Cyclotella* was discovered near the Aderan Village, downstream of the Amir Kabir Dam about 12 km along the road from Karaj to Chalous (35°53´N, 51°4´ E, elevation 1555 m).

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The new species, named here as *Cyclotella iranica sp. nov*, is described using light (LM) and scanning electron microscopy (SEM). Its relationship to allied *Cyclotella* species is discussed.

Material and methods

Epipelic and epilithic samples were collected from six sites (Fig. 1) along the Karaj River:

Site 1. Downstream of the Amir Kabir Dam, 35°50´N, 51°4´ E, elevation 1405 m, near the village of Kondor at Sarvdar Path.

Site 2. Downstream of the Amir Kabir Dam, 35°53´N, 51°4´ E, elevation 1555 m, near the village of Aderan.

Sites 3. Upstream of the Amir Kabir Dam, 36°01´N, 51°8´ E, elevation 1802 m, near the village of Khab bridge.

Site 4. Upstream of the Amir Kabir Dam, 36°0 2´N, 51°14´ E, elevation 1887 m, near the village of Kiasar.

Site 5. Upstream of the Amir Kabir Dam, 36°02´N, 51°18´ E, elevation 2036 m, near the village of Kasil.

Site 6. Upstream of the Amir Kabir Dam, 36°07´N, 51°18´ E, elevation 2222 m, between the Gachsar and Welayat Rud villages.

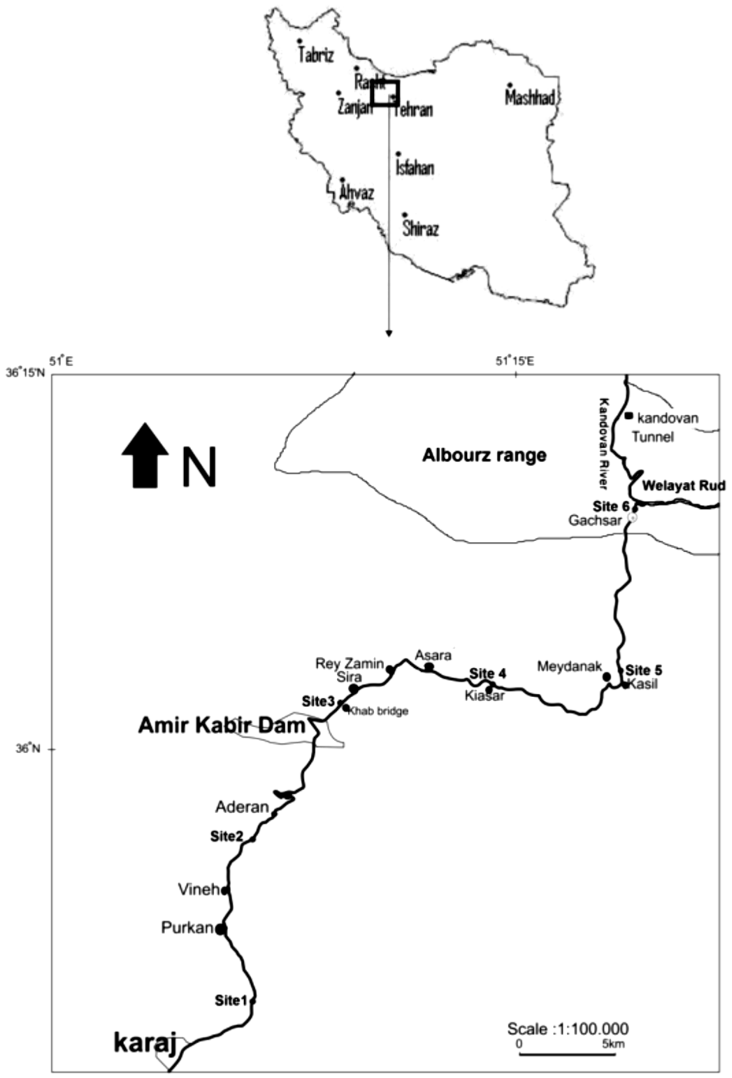


FIGURE 1. Map of Karaj River, sampling sites marked with numbered black dots, adapted from geological map of the terrain of Marzan Abad and Tehran. Marzan Abad is a region located along the road from Karaj to Chalous, 30 km from Kandovan Tunnel.

For collecting epipelic samples, a plastic syringe (with a capacity of 60 ml and diameter of 29.1 mm) with the barrel cut off at the needle adapter end was inserted into the substrate. The plunger was pulled along the barrel to admit 25 ml of the epipelic sample to flow in. The cut end of the syringe was then shut by means of a spatula to transfer the sample into the preservative solution (4% formaldehyde, CH_2O) in a 30 ml bottle. Epilithic samples were collected from a rock by brushing 100 cm^2 of the rock surface. Material was transferred into a 30 ml bottle containing the preservative solution and transported to the laboratory of Islamic Azad University of Tehran. The samples were treated with 25–30 ml 30% hydrogen peroxide (H_2O_2) (1.5 hours at 100 °C) and then 10 ml hydrochloric acid (HCl) (2 hours at 120 °C) for the removal of organic matter and carbonates. Excess acid was removed by repeated rinsing and settling with distilled water.

Coverslips were prepared with the diatom suspension and mounted on slides in Zrax. For LM images, slides were examined using a Leica DMRB microscope under a 100x oil immersion objective (1.4 NA) with differential interference contrast (DIC). Images were gathered and analyzed with a Qimaging 3.3 M camera and software at the Iowa Lakeside Laboratory (Milford, Iowa, U.S.A.).

Cleaned material for SEM was placed on aluminum stubs and air dried. These stubs were coated with gold (Emitech K550, 20 mA, 1.5 min) before being viewed using an LEO 440i scanning electron microscope operated at 15 kV in the SEM center of the Islamic Azad University of Tehran Branch of Science and Research. Additional SEM images were taken at the Wartburg College SEM Center (Waverly, Iowa, U.S.A) using a Hitachi S-2460N SEM.

Comparison with *Cyclotella delicatula* Hustedt (1952: 376) was based on type material (BRM AC1/87, holotype, AC1/88, AC1/89; see Simonsen 1987: 381 and Houk *et al.* 2010: 32, 292-299); comparison with *C. fotti* Hustedt (in Huber-Pestalozzi 1942: 400) was based on Levkov *et al.* (2007) and Houk *et al.* (2010: 25, 224–229); comparison with *C. krammeri* Håkansson (1990: 263) was based on Håkansson (1990); comparison with *C. andancensis* var. *andancensis* Ehrlich (1966: 316) was based on Ehrlich (1966) and Serieyssol (1981); comparison with *C. andancensis* var. *bauzilensis* Serieyssol (1981: 29) and *C. andancensis* var. *bipolaira* Serieyssol (1981: 31) was based on Serieyssol (1981). Additional taxonomic comparisons were made using Krammer and Lange-Bertalot (1991).

Valve terminology follows Theriot & Serieyssol (1994) and Houk *et al.* (2010: 6). Stria density in 10 µm was measured by counting the total striae on the disc face, dividing it by the circumference of the valve and then multiplying that by 10.

Environmental factors, including dissolved oxygen (DO) and electrical conductivity (EC) of the water of the river, were measured *in situ* with a portable DO meter (WTW Oxical-SL Model CellO×3205) and an EC meter (Crison Model CM 35) respectively. Water samples were transported to the laboratory for further analysis, with the results summarized in Table 3.

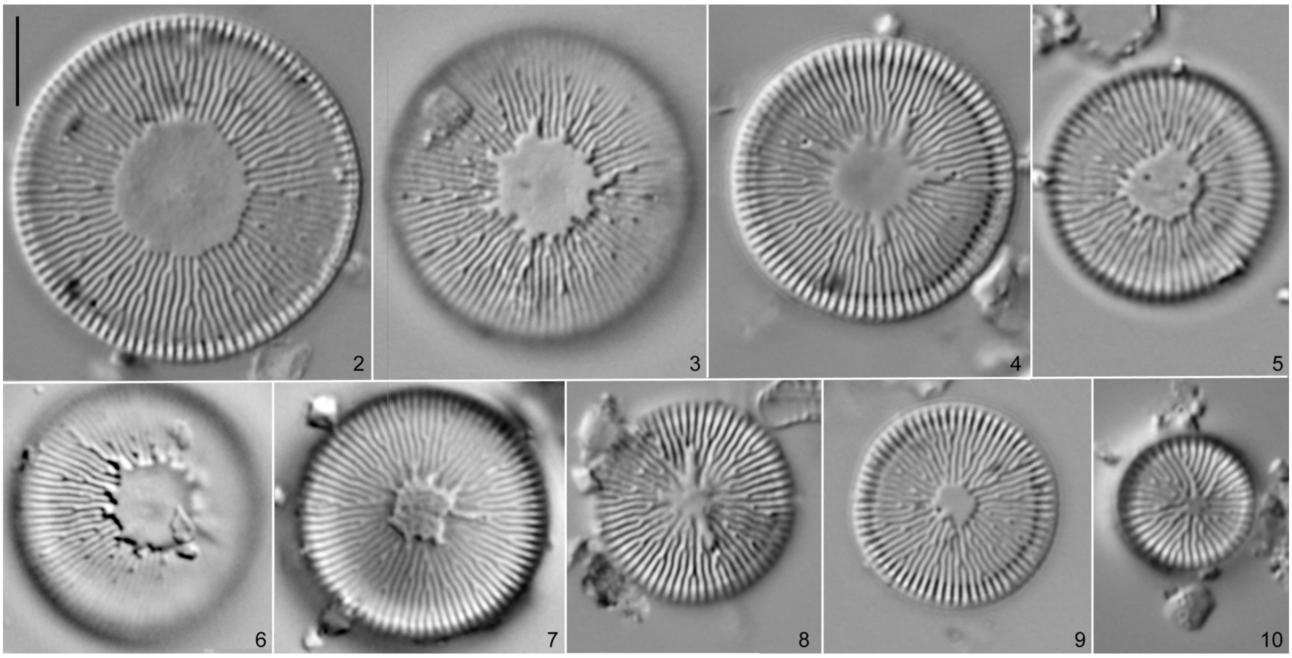
New species description

Cyclotella iranica Nejadsattari, Kheiri, Spauld., & Edlund *sp. nov.* (Figs 2–14)

Frustules cylindrical, valves disc-shaped, valve face smooth, flat with alveolate multiseriate striae on margin; 5.5–15.8 µm in diameter. Striae vary in length, extending to mantle, 18–23 in 10 µm. Mantle fultoportulae located every 3-6 costae, central fultoportula(e) (1–3) mostly at proximal end of shorter striae. One rimoportula located on a costa, in larger valves within striae, in smaller valves near valve face-mantle junction.

Type:—IRAN. Albourz, Karaj, Karaj River, downstream of the Amir Kabir Dam, near the village of Aderan, elevation 1555 m, 35°53´N, 51°4´E, epipelon, collected 17 October 2011, *M. M. Hamdi* (ANSP GC38094, circled specimen, **holotype! designated here** (= Fig. 4), prepared from material ANSP GCM22001; IAUGH slide 5892, ANSP GC38095, prepared from material ANSP GCM22002, **isotypes! designated here**).

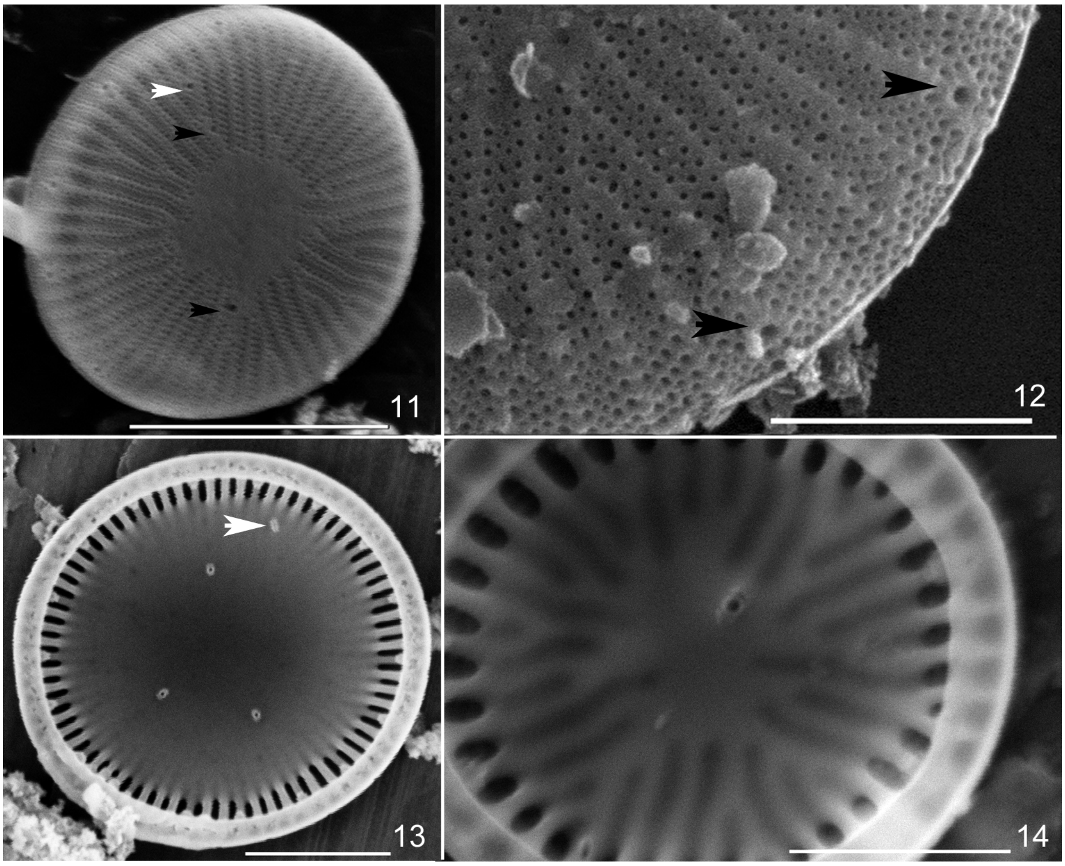
Valve face ornamented with two distinct parts: a hyaline central area and a marginal striated region; central area roughly 1/4–1/7 of total valve diameter. Striae alveolate and multiseriate, with 3–4 rows of fine porelli (not readily seen in LM); alveolar openings very short and small in relation to striae length (Figs 13–14). Stria density 18–23 in 10 µm; valve diameter varies from 5.5–15.8 µm (Figs 2–10). Striae differ in length, arranged in pseudo-sectored groups of branching striae around whole valve (Figs 11–12). 1–3 central fultoportulae present, arranged randomly, mostly at proximal end of shorter striae (Fig. 4) or rarely at central end of a longer stria (Figs 10, 5, 9). Central fultoportulae have two satellite pores and no ornamentation on external opening of central tube. Marginal fultoportulae present on every third to sixth costae, near junction of valve face/ mantle (Figs 13–14). Marginal fultoportulae have two satellite pores, open to valve exterior through unornamented central pore. One rimoportula situated on a costa between two adjacent foramina or, in larger valves, slightly advalvar to a foramen (within the striated valve part); rimoportula observed only under SEM, it is a sessile labium internally and variously oriented from radially to tangentially; external opening is a simple unornamented pore (Figs 12–14).



FIGURES 2–10. *Cyclotella iranica*, ANSP GC38094, Fig. 4 is holotype specimen. All images are LM and in valve view. Scale bar: 5 µm.

Observations:—Among the many known species of *Cyclotella*, *C. iranica* is most similar to *C. delicatula* (see Scheffler *et al.* 2003, Houk *et al.* 2010). Like *C. iranica, C. delicatula* has an irregular central area with a similar valve diameter size range (Table 1). However, the central area in *C. delicatula* is more or less transversally undulate and colliculate with pori or hollows. In contrast, *C. iranica* has a flat central area without colliculae, pori or hollows (when seen in SEM). Moreover, granules are concentrically arranged in rows on the costae of the valve view in *C. delicatula*, a feature that differentiates it from *C. iranica* (also in SEM). The most distinctive difference between *C. delicatula* and *C. iranica* is that *C. delicatula* possesses 1-2 fultoportulae near the valve center, opposite the rimoportula (Houk *et al.* 2010, Scheffler *et al.* 2003, Kiss *et al.* 2012). In *C. iranica*, there is one, or in larger valves, up to three, central fultoportulae situated near the central end of a stria along the edge of the central area. Furthermore, the central area/valve diameter ratio in *C. iranica* is less than that of *C. delicatula*.

Cyclotella iranica shares a similar stria pattern, central area and approximately similar central area/ diameter ratio with *C. fottii* (as in Levkov *et al.* 2007 and Houk *et al.* 2010) but *Cyclotella iranica* differs in having a smaller, flat central area, stria density (in 10 µm), valve diameter range and the presence of a central fultoportula. *C. iranica* does not have marginal spines and its marginal fultoportulae are not visible in LM, both of which are characters of *C. fottii* (Houk *et al.* 2010).



FIGURES 11–14. SEM images of *Cyclotella iranic*a, Karaj River, Iran. Figs 11–12, 14. Isotype material IAUGH. Fig. 13. Holotype material ANSP GCM22001. Fig. 11. External view showing central fultoportulae (black arrowheads) and the single rimoportula on the valve face (white arrowhead). Fig. 12. External view showing areolae within striae and the marginal fultoportulae (white arrowhead). Fig. 13. Internal view of the valve face. The single rimoportula on the valve face has an oblique orientation (white arrowhead. Numerous marginal fultoportulae are present). Fig. 14. Internal view of a small valve with a single central fultoportula and two satellite pores. Scale bars = 5 μm (Figs 11–13); 2 μm (Fig. 14).

Cyclotella iranica can be compared to some Miocene fossil species such as *C. andancensis*, *C. andancensis* var. *bauzilensis* and *C. andancensis* var. *bipolaira* (Ehrlich 1966, Serieyssol 1981). All of these taxa share features with *C. iranica*, such as the unequal striated pattern of the valve, the presence of one rimoportula, and its orientation, and the nearly similar central area/diameter. However, they all differ from *C. iranica* by the absence of a central fultoportula and the colliculate ornamentation of central area. The alveolar openings in *C. andancensis* var. *andancensis* are the same size as those found in *C. iranica*, but are different in size when *C. andancensis* var. *bauzilensis* and *C. andancensis* var. *bipolaira* are compared with *C. iranica*.

Cyclotella krammeri (Håkansson 1990) is also similar to *C. iranica* in having an unequal striation to the valve face, the presence of central fultoportulae and the size of alveolar openings. However, it has a larger central area than *C. iranica*, with pori and papillae, and more central fultoportulae, which are located in the center of the valve in contrast to *C. iranica* where the central fultoportulae are located at central end of striae.

Ecology and biogeography:—Habitat, Epipelic or epilithic. There is limited ecological and biogeographical information on *Cyclotella iranica* as it is described here for the first time. From a biogeographical standpoint, the distribution of *Cyclotella iranica* currently limited to the Karaj River basin in Iran, its type locality. No other illustrations of this taxon have been located in the literature. Further efforts are needed to determine if this taxon is indeed limited to just the Karaj Basin or if additional populations are to be found throughout the Middle East.

TABLE 1. Comparison of morphological features for selected species of *Cyclotella.*

	C. iranica	***C. fottii*** [1,2]	***C. delicatula*** [1,3,4]	***C. krammeri*** [5]	***C. andancensis* var. *andancensis*** [6,7]	***C. andancensis* var. *bauzilensiis*** [7]	***C. andancensis* var. *bipolaira*** [7]
Valve diameter	5.5–15.8	16.7–55.0	5.9–7.4 (5.9–15.7)	18.8–26 (8–40)	13–18 (8–16–20)	(4–10)	(5–10)
Striae in 10 µm	18–23	9–14	20-22 (17–22)	32–46 (12–18)	25–40 (14–20)	(18–20)	(16)
Central area/diameter	1/4–1/7	1/4–1/6	1/2–1/3	1/2–1/3	1/5–1/8	1/3–1/4	1/3–1/4
Shape of central area and ornamentation	Round to star like, no ornamentation	Round, papilla and pori or blank	Round, papilla and pori or blank	Round, papilla? and pori	Round, pori	Round, papilla and pori	Oval, papilla and pori
Number of central fultoportulae	0–3	0	0–2	3–5	0	0	0
Position of central fultoportulae	Central end of a stria	-	Center valve	Center valve	-	-	-
Position of marginal fultoportulae	Every third to sixth costa	Every second to forth costa	Every fourth to eighth costa	Every third to sixth costa	Every third to eighth costa	Every sixth to eighth costa	Every fourth to sixth costa
Alveolar opening length	Very short in relation to stria length	Very short in relation to stria length	Very short to 1/3 length of stria	Very short in relation to stria length	Very short in relations to stria length	1/2 length of stria to almost as long as stria	1/3 to 1/2 length of stria to almost as long as stria
Rimoportula(e)	1	3–8	1	1?	1	1	1
Position of rimoportula(e)	On a costa, at margin of face in small valves, more advalvar in large valves	Striated part of valve	On a costa, at margin of face in small valves, more advalvar in large valves	Striated part of valve?	Inner end of a costa, (Striated part of valve)?	On a costa, at valve margin	On a costa, at valve margin
Orientation of rimoportula(e)	Radial or oblique, rarely tangential	Radial or oblique	Radial or oblique	Radial or oblique	Tangential	Radial	Radial
Marginal spines	Absent	On costae	Absent	Absent	Absent	Absent	Absent
Colliculate costae	Absent	Present	Absent	Absent	Absent	Absent	Absent
Granules	Absent	Absent	On costae, in concentric rows	If present, on costae	Absent	Absent	Absent
Valve face	Flat	Transversally undulate	Flat to transversally undulate	Slightly undulate to flat	Transversally undulate	Transversally undulate	Transversally undulate

[1]Houk *et al.* (2010), [2]Levkov *et al.* (2007), [5] Håkansson (1990), [7]Serieyssol (1981), [3] Scheffler *et al.* (2003), [4]Black *et al.* (2012), [6]Ehrlich (1966)

TABLE 2. *Cyclotella iranica* from sites (1-6) along Karaj River chronologically (10.4.2011—11.3.2012).

	10.4. 2011	11.5. 2011	7.6. 2011	17.7. 2011	15.8. 2011	20.9. 2011	17.10. 2011	20.11. 2011	18.12. 2011	15.1. 2012	21.2. 2012	11.3. 2012
Site 1	ND	ND	-	ND	-	-	*	-	-	*	-	*
Site 2	ND	ND	rare	*	*	*	*	*	*	*	*	*
Site 3	rare	rare	rare	rare	-	-	-	-	-	-	-	-
Site 4	-	rare	-	rare	rare	-	-	rare	-	-	-	-
Site 5	-	-	-	-	-	-	*	rare	-	-	-	-
Site 6	-	-	-	-	rare	-	-	-	-	-	-	-

ND: No diatoms present, high amount of inorganic sediment
Rare**:** Abundance very low, with 1–2 specimens from among c. 100 valves
-: Absent
*: Present at >2% relative abundance

Physicochemical factors taken in the field and laboratory (Table 3) suggest that *Cyclotella iranica* is found in epipelic and epilithic collections from alkaline rivers, and that it is tolerant of nutrient and organic enrichment as evidenced from the low dissolved oxygen and high BOD and COD of the type locality (Table 3). Among the sampling sites, *C. iranica* was found commonly only at Karaj River Sites 1 and 2 (Table 2). There was no strong seasonality in the abundance of *C. iranica* as it was found at any time of the year; it was most prevalent during the summer and fall months.

TABLE 3. Physical and chemical parameters recorded from Karaj River at the type locality (17 October 2011).

Parameter	**Units**	**Parameter**	**Units**
Temperature	13.7±5 °C	Cl	276.53 mg l^{-1}
Specific conductance	302 µS cm^{-1}	SiO_2	12.5 mg l^{-1}
pH	8.41	COD	32.6 mg l^{-1}
Ca	30 mg l^{-1}	BOD	17 mg l^{-1}
Mg	6.5 mg l^{-1}	DO	7.1 mg l^{-1}
Na	9.26 mg l^{-1}	SO_4	32.8 mg l^{-1}
K	0.1 mg l^{-1}	NO_3	4.26 mg l^{-1}

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