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Original Article

The trophic status of the Zayandeh River dam lake in the spring and summer, 2017

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Abstract: The Zayandeh River dam lake, supplies freshwater for municipal, agricultural and industrial activities of three central Iranian provinces. Monthly water sampling was conducted in the spring and summer 2017 at four stations in the lake to determine trophic state. Electro-conductivity, temperature, pH, turbidity, total suspended solids, total dissolved solids, nitrate, phosphate, dissolved oxygen, biological oxygen demand also chlorophyll-a levels were measured in the samples. The maximum value of Trophy State Index (TSI) was recorded in May and the minimum value in September. Based on TSI, the Lake was oligotrophic in the spring and summer. However, in the May, the lake was in mesotrophic state, probably due to floods, runoff and drainage of farmlands. Due to high temperatures and biological activity in the summer, nitrate and phosphate decomposition increased. On the other hand, agricultural activities decreased compared to the spring, resulted in decreases in the concentration of nutrients, especially nitrate. Therefore, the lake is in oligotrophic state from June to September.

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Introduction

Eutrophication is a harmful environmental phenomenon in inland waters such as lakes, reservoirs, rivers, estuaries and other habitats (Fernández et al., 2009; Rigosi et al., 2014), which occurs due to increase in the concentration of nutrients, especially nitrogen and phosphorus (Wilkinson, 2017). Increase in application of nitrogenous and phosphorous fertilizers has increased agricultural crops production, but led to serious problems, such as algae bloom, change in diversity and abundance of aquatic species and water quality (Huang et al., 2017). These impacts threaten the trophic state and ecological sustainability in aquatic ecosystems. Eutrophication also causes water turbidity and replacement of macrophytes by phytoplanktons (Portielje and Van der Molen, 1999). A range of water quality parameters, such as physical, chemical and biological parameters and primary production are evaluated to monitoring trophic state (Hollister et al., 2016). Trophic state in freshwaters is determined based on total phosphorous, total nitrogen and chlorophyll-a concentrations. Resident time, depth, geology and morphology of lakes, industrial wastewater, aquaculture and fertilizers are effective in trophic state of the lakes (Brönmark and Hansson, 2005).

Eutrophication is directly linked to primary production by phytoplankton. These organisms play an important role in the environment. However, high concentrations of certain species may lead to health problems for humans and aquatic organisms. Cyanobacteria create toxins that can cause serious liver, nervous system diseases and death at certain concentrations. Phytoplankton has photoactive pigments that may be used to identify these toxins (Watanabe et al., 2015). Trophic state in freshwaters has been the subject of several researches in the world (Rigosi et al., 2014; Yang et al., 2016; Boucek et al., 2017; Lee and Liu, 2018; Kiersztyn et al., 2018) as well as Iran (Saghi et al., 2015; Ghorbani et al., 2016; Taheri Tizro et al., 2016; Esfandi et al., 2018).

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Table 1. Carlson classification for trophic status (OECD, 1977).

Trophic state	TSI
Oligotrophic	0-40
Mesotrophic	40-60
Eutrophic	60-100

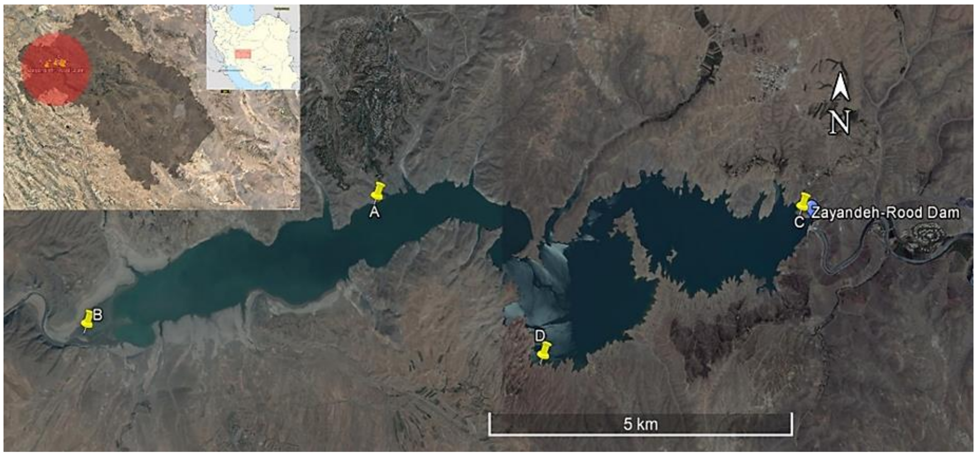

Figure 1. Geographical map of sampling stations.

Chlorophyll-a (Chl-a) presents in all phytoplankton species (Watanabe et al., 2015) and is an efficient indicator of water eutrophication (Malek et al., 2011). There are several linear models for Chl-a concentration and environmental variables. To date, several trophic models have been presented by researchers. One of the most important and common models is Trophic State Index (TSI) that was introduced by Carlson (1977).

The Zayandeh River with more than 350 km length (Nabinejad, 2018), is the most important river in central Iran with semi-arid region (Safavi et al., 2014). The Zayandeh River drainage has water supply from the central Zagros Mountains, covers 41,500 km^2 and finally enters the Gavkhuni international wetland (Babaei et al., 2013; Sanayei et al., 2009). The Zayandeh River Dam Lake, locating 110 km west of Isfahan City (32°44′ 06.51″N, 50°44′15.75″ E), covers an area of 54 km^2 and has capacity to hold 150×10^6 m^3 water (Shams et al., 2012). The lake supplies freshwater for municipal, agricultural and industrial activities of three central Iranian provinces (Hajian and Rahsepar, 2010). According to the importance of the lake (as mentioned above), it is important to monitor its water quality; therefore, this study aimed to assess the trophic state of the Zayandeh River dam Lake in the spring and summer of 2017.

Materials and Methods

Sampling: The Randomized Complete Block Design (RCBD) (Anderson and McLean, 2018) was used to choose 4 sampling sites in the north (A: Chadegan), west (B: Mashhad Kaveh), east (C: Hojjatabad) and south (D: Yancheshmeh) of the lake (Fig. 1). Monthly sampling of surface water was done in the spring and summer, 2017. All samples were collected at 10 am to 2 pm. From each station, three 1.5-liter dark bottles of water were collected and transferred to the laboratory under controlled conditions. The water temperature was measured in the sampling site; whereas, electro-conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), pH, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD_5), nitrate and phosphate were determined according to APHA (2005). The samples' Chl-a content was measured according to Arnon (1967).

Chl-a Extraction: All samples were transferred to the laboratory at 4°C. In order to determine the chlorophyll contents, the samples were extracted, using 80% acetone. The supernatant was used to measure the absorbance with a spectrophotometer (Arnon, 1967). Finally, Chl-a content was determined at 663 and 645 nm.

Table 2. Modified Carlson classification for trophic status (OECD, 1982).

		Oligotrophic	Mesotrophic	Eutrophic
Total PO_4(µg/l)	Mean	8	26.7	84.4
	Range	3.7-17	9.6-10.95	16-386
Total NO_3(µg/l)	Mean	661	753	1857
	Range	307-1630	361-1387	393-6100
Chlorophyll-a(µg/l)	Mean	1.7	4.7	14.3
	Range	0.4-3.5	3-11	3-87

Table 3. Analysis of variance between the stations.

Parameters	Stations		Months	
	F-value	*Pvalue*	*F-value*	*Pvalue*
pH	0.372	0.77	2.911	0.058
EC (µmhos/cm)	0.462	0.713	3.842	0.024*
Turbidity (NTU)	7.43	0.002	0.404	0.803
TDS (mg/l)	0.459	0.715	3.805	0.025*
TSS (mg/l)	0.822	0.501	1.60	0.225
DO (mg/l)	0.919	0.454	3.023	0.052
BOD_5 (mg/l)	0.037	0.990	6.22	0.004*
PO_4^- (mg/l)	0.932	0.448	2.43	0.008*
NO_3^- (mg/l)	0.4	0.755	1.31	0.093
Chlorophyll-a (µg/l)	0.280	0.839	0.842	0.52
Ambient temperature (°C)	0.016	0.997	4.47	0.014*
Water temperature (°C)	1.45	0.265	7.83	0.001*

*Significant difference at 0.05; ** Significant difference at 0.01

$$\text{Chl-a (mg/ g tissue)} = (12.7\ (A_{663}) - 2.69\ (A_{645}))\times V/1000 \times W$$

Where V is the final volume of Chl-a extract in 80% acetone, A= absorbance of specific wavelength and W= fresh weight of Tissue extract.

TSI: TSI (Carlson, 1977) was developed based on transparency as relative indicators of algae biomass, that is the most suitable and acceptable method for evaluating inland lake's eutrophication (Duan et al., 2007). But several studies have claimed that transparency is influenced by various factors (Aizaki et al., 1981). Therefore, modified Carlson index was proposed based on Chl-a concentration (Table 1), with 0–100 continuous numerical classes of lakes trophic states (OECD, 1982).

Statistical analyses: All data were tested in terms of normality and homogeneity of variance before conducting parametric statistical analysis. Variability among sampling sites was analyzed for each water parameter by one-way ANOVA. To detect differences among individual mean, we used Duncan Multiple range test. The relationships among the tested parameters were evaluated by Pearson correlation (P<0.05) using SPSS software (Van Belle et al. 2004; Thode, 2002).

Results

Analysis of variance between the sampling stations and times are presented in Table 3. The results of comparison between the stations and times are reported in Tables 4 and 5, respectively. Based on the results, turbidity showed significantly different between the stations and the highest value was observed in the station B (Mashhad Kaveh).

According to the results (Table 5, Fig. 2), the lowest and highest EC and TDS were found in August and June, respectively. The highest water TDS, BOD_5 and PO_4^- were recorded to June (spring), August (summer) and May (spring), respectively. The lowest TDS was recorded in the summer and the lowest BOD_5 in May and September. There was no significant difference in PO_4^- levels between the spring and summer, except in May that had the highest value. The highest water and ambient temperature

Table 4. Mean comparison (Duncan) between the stations.

Parameters	Station A	Station B	Station C	Station D
pH	7.58±0.41^{A}	7.59±0.28^{A}	7.71±0.13^{A}	7.72±0.17^{A}
EC (µmhos/cm)	288.7±39.11^{A}	318.46±37.78^{A}	310.22±40.25^{A}	299.36±51.73^{A}
Turbidity (NTU)	2.68±0.87^{B}	16.28±11.45^{A}	2.26±1.65^{B}	1.48±0.68^{B}
TDS (mg/l)	152.00±21.20^{A}	168.00±20.28^{A}	164.40±21.76^{A}	158.00±27.28^{A}
TSS (mg/l)	7.60±4.04^{A}	5.60±0.89^{A}	5.60±1.52^{A}	5.40±2.61^{A}
DO (mg/l)	6.28±0.13^{A}	6.50±0.47^{A}	6.20±0.52^{A}	6.58±0.43^{A}
BOD5 (mg/l)	6.70±0.52^{A}	6.64±0.47^{A}	6.68±0.50^{A}	6.74±0.43^{A}
PO_4^- (mg/l)	0.82±0.045^{A}	1.14±0.078^{A}	0.62±0.027^{A}	0.6±0.022^{A}
NO_3^- (mg/l)	6.26±1.68^{A}	7.18±0.87^{A}	6.54±1.53^{A}	6.88±1.34^{A}
Chlo-a (µg /l)	2.9±0.16^{A}	5.02±0. 24^{A}	4.06±0. 24^{A}	3.86±0. 27^{A}
Ambient T(°C)	22.60±1.95^{A}	23.00±4.30^{A}	22.60±3.21^{A}	23.00±5.96^{A}
Water T(°C)	17.80±2.49^{A}	14.20±3.56^{A}	14.20±3.27^{A}	14.60±3.51^{A}

Similar letters mean non-significant difference among the stations.

Table 5. Mean comparison (Duncan) between the sampling time and the results of TSI index.

Parameters	May	June	July	August	September
pH	7.87±0.13^{A}	7.74±0.22^{A}	7.59±0.22^{AB}	7.37±0.31^{B}	7.68±0.17^{AB}
EC (µmhos/cm)	337.38±23.85^{AB}	339.50±14.93^{A}	287.88±20.08^{BC}	281.45±61.09^{C}	275.05±16.70^{C}
Turbidity (NTU)	8.35±2.48^{A}	4.01±1.38^{A}	9.00±4.03^{A}	2.77±0.75^{A}	4.22±1.64^{A}
TDS (mg/l)	178.00±12.73^{AB}	179.25±7.80^{A}	151.75±10.84^{BC}	147.75±32.82^{C}	145.00±8.76^{C}
TSS (mg/l)	8.50±3.42^{A}	6.50±3.79^{A}	5.00±0.82^{A}	5.00±0.82^{A}	5.25±0.96^{A}
DO (mg/l)	6.00±0.16^{A}	6.83±0.42^{A}	6.45±0.21^{A}	6.43±0.55^{A}	6.25±0.24^{A}
BOD_5 (mg/l)	6.28±0.10^{C}	7.05±0.51^{AB}	6.60±0.18^{BC}	7.13±0.32^{A}	6.40±0.26^{C}
PO_4^- (mg/l)	1.6±0.08^{A}	0.5±0.01^{B}	0.5±0.01^{B}	0.5±0.01^{B}	0.87±0.01^{B}
NO_3^- (mg/l)	7.92±0.85^{A}	7.13±0.22^{A}	6.78±0.34^{A}	6.24±1.86^{A}	5.53±1.54^{A}
Chlo-a (µg/l)	5.37±0.34^{A}	2.37±0.22^{A}	3.15±0.23^{A}	2.80±0.28^{A}	2.20±0.22^{A}
Ambient T (°C)	19.00±2.58^{B}	20.50±1.00^{B}	25.75±4.99^{A}	23.00±2.73^{A}	25.75±0.96^{A}
Water T (°C)	12.25±1.26^{C}	12.75±2.87^{C}	15.25±3.30^{B}	16.00±1.41^{B}	19.75±0.50^{A}
TSI (Chlorophyll-a)	44.6	31.75	37.8	35.1	35.9

Similar letters mean non-significant difference between the sampling times.

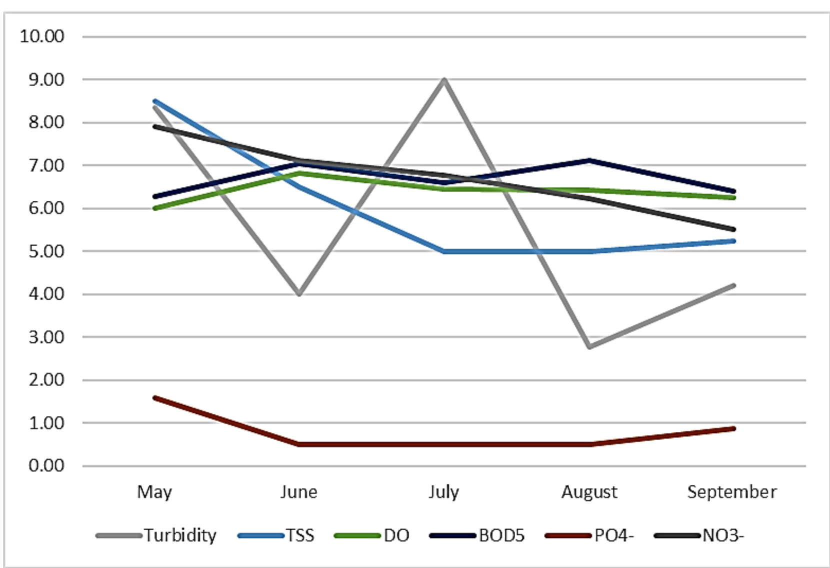

Figure 1. Variations of water quality parameters among the sampling time.

Table 6. Pearson correlations between the tested parameters.

	pH	EC	Turbidity	TDS	TSS	DO	BOD^5	PO_4^-	NO_3^-	Col. a	Ambient T	Water T
pH	1	0.47	10.0**	0.48	0.28	-0.29	-0.61	0.40	0.31	60.1*	-0.29	-0.13*
EC	0.47	1	0.00*	1	0.34	90.0*	-0.10*	20.1*	0.77	40.1*	-0.53	-0.57
Turbidity	0.01**	0.00**	1	0.00**	-0.10*	50.0**	-0.13*	0.46	10.0**	0.37	80.0**	-0.26
TDS	0.48	1	0.00**	1	0.34	90.0*	-0.11*	30.1*	0.77	50.1*	-0.52	-0.57
TSS	0.28	0.34	-0.10*	0.34	1	-0.34	-0.47	30.1*	0.44	0.38	-0.25	-0.13*
DO	-0.29	0.09*	50.0**	90.0*	-0.34	1	0.65	-0.42	40.0**	-0.14*	0.02**	-0.29
BOD5	-0.61	-0.10*	-0.13*	-0.11*	-0.47	0.65	1	-0.50	-0.23	-0.34	0.00**	-0.20*
PO_4^-	0.40	0.12*	0.46	30.1*	30.1*	-0.42	-0.50	1	0.11	50.1*	-0.31	-0.15*
NO_3^-	0.31	0.77	10.0**	0.77	0.44	40.0**	-0.23	10.1*	1	0.33	-0.51	-0.51
Chlo.a	60.1*	0.14*	70.3*	0.15	80.3*	-0.14	-0.34*	0.15	30.3*	1	-0.25	-0.32
Ambient T	-0.29	-0.53	80.0**	-0.52	-0.25	-0.02**	0.00**	-0.31	-0.51	-0.25	1	0.51
Water T	-0.13*	-0.57	-0.26	-0.57	-0.31*	-0.29	-0.20*	-0.15*	-0.51	-0.32	0.51	1

* Significant difference at 0.05 ** Significant difference at 0.01

were observed in the summer (July, August and September) and the lowest in the spring (May and June). There was no significant difference in Chl-a content between the sampling stations. According to TSI (Table 5), Chl-a was higher in May compared to the other times.

Discussions

Based on the results, pH, TSS, turbidity, DO, NO_3 and Chl-a were relatively stable in the spring and summer, as there were no significant differences. The highest phosphate concentrations were measured in May, which might be as a result of raining and input of agricultural drainage to the dam lake. The highest and lowest water temperatures were measured in August and May, respectively and the highest water turbidity in the station B (Mashhad Kaveh), which might be due to water turbulence near the station.

Based on TSI (Chl), the mean trophy level of the Zayandeh River dam Lake in the spring and summer is oligotrophic. However, the lake is in mesotrophic state in the spring (May), probably due to floods, runoff and drainage of farmlands. Due to high temperatures and biological activity in the summer, nitrate and phosphate decomposition increases. On the other hand, the concentration of the nutrients especially nitrate decreased compared to the spring, probably due to decreases in agricultural activities. Therefore, the lake was oligotrophic from June to September. Shams et al. (2012) reported that Zayandeh River Dam Lake is oligo-mesotrophic based on the seasonal variations in phytoplankton communities. Based on Chl-a measurment, Movahhedinasab (2013), in the spring and summer, and Rajae (2013), in the autumn and winter, categorized the lake as oligotrophic. According to TSI(SD) and TSI(Chl), Malekzadeh (2014) reported the lake as mesotrophic. Based on physical and chemicals parameters and phytoplankton communities, Hamidi et al. (2014) classified the lake as oligo-mesotrophic. Khalaji et al. (2017) estimated that the water quality of the Zayandeh River's Dam Lake is good (50-100) based on WQI. The main notable point is that the eutrophic is often equal to poor water quality. The quality of water depends on the water applications and the local attitude of the people. The concept of trophic status and its index should be merely a framework for assessing water quality and should remain neutral to such subjective judgments.

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