Water quality assessment in Choghakhor Wetland using water quality index (WQI)

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Abstract

The Choghakhor International Wetland plays an important role in preserving and protection of part of the plant and animal species in the Iranian plateau. Since the water of this wetland is utilized for different human purposes, complete periodic chemical and physical quality assessment of its water seems necessary. Water quality index (WQI) was calculated using the following eleven parameters: Nitrate, Nitrite, Ammonium, Alkalinity, Hardness, Turbidity, Conductivity, Dissolved Oxygen, Total Dissolved Solid, pH and Biochemical Oxygen Demand (BOD_5). For this purpose, the relative weight assigned to each parameter ranged from 1 to 4 based on the importance of the parameter for aquatic environment and human health. The analyses of variance (ANOVA) of data revealed significant differences between different periods of sampling ($p<0.01$). Therefore we assigned the results in two categories: very poor and inappropriate, which make it not suitable for human uses such as drinking. The most important factor in assessment of water quality in this study was BOD_5. The result of this research demonstrated that this method can be used for assessment of water quality in wetlands.

Keywords: Choghakhor Wetland, Chaharmohal Bakhtiari**,** Physicochemical factors, Water quality index**,** Iran

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Introduction

The growth of population in the last few decades in Iran have resulted in steady demand for more food and water supply and resources. Over exploitation of surface and underground water resources for the agricultural, industrial and other purposes plus the adverse effects of climate change have resulted in sharp reduction of our water resources. Therefore various national plans and resource management programs should be implemented in order to revive and save our water resources. Maintaining, protecting and improving quantity and quality of water resources necessitates implementation of monitoring programs to quantify changes and make decisions and policies based on this information (Odmis and Evrendilk, 2008; Qian *et al.*, 2007). The phrase "water quality" has been developed to give a comprehensive indication of suitability of water resources for human consumptions (Vaux, 2001). This term is widely used in various sciences and related cases and is considered as a necessity to manage water resources (Parparov *et al.*, 2006). Water quality in aquatic ecosystems is determined by many physical, chemical and biological factors (Sargaonkar and Deshpande, 2003). Therefore, particular problem in the case of water quality monitoring is the complexity associated with analyzing the large number of measured variables (Boyacioglu, 2006). The high variability of water resources is due to anthropogenic and natural influences (Simeonov *et al.*, 2002). There are a number of methods for analysis of water quality data which may vary depending on the goals and information needed, the study area, sample size and sampling methods (Simeonov *et al.*, 2002; Boyacioglu, 2007a). One of the most effective methods to assess water quality is using appropriate indices (Dwivedi, 2007). Indices are based on the values of various physico-chemical and biological parameters in a water sample. The use of indices in monitoring programs have been very useful for assessment of ecosystem health and also can be used as a benchmark for appropriate and successful assessment in management strategies for improving water quality (Rickwood and Carr, 2009). Water quality index (WQI) can be used to collect data on water quality parameters at different times and places and to translate the information into a single value based on certain period of time and spatial unit (Shultz, 2001). The National Sanitation Foundation Water Quality Index (NSF WQI) is one of the first water quality indices (Brown *et al.*, 1970). Based on the results of WQI, water can be classified for various purposes (Brown, 1970). Pesce and Wunderlin (2000) used water quality indices to assess the water quality of the Suquia River in Argentina (Pesce and Wunderlin, 2000). Alobaidy *et al.* (2010) applied WQI for water quality assessment of Dokan Lake in Kurdistan Region, Iraq from 1976 to 2000 period to be compared with 2008 to 2009. The results revealed a decline in water quality from good to poor (Alobaidy *et al.*, 2010). Nemati *et al*. (2009) used water quality indices to assess the water quality of Zayandehrud River (Nemati Vernosfaderany *et al*., 2009). Choghakhor Wetland is located in a cold and dry region in central Iran plateau; without any program for the assessment of its water quality and appropriate management (Shivandi *et al.*, 1999). This study is an attempt to assess temporal and spatial changes in Choghakhor water quality.

Materials and methods

Study area

The study area was choghakhor Wetland with an area of about 2300 hectars. This wetland is located in Gandoman-Boldaji plain of Chaharmahal Bakhtiari Province. Gandoman-Boldaji plain is located between 31°50' to 32°00′ northern latitudes and 51°00′ to 51°10′ eastern longitudes (Shivandi *et al.*, 1999). The sampling was performed at eight stages with a time interval of 45 days in four seasons, from May to March 2010. Ten sampling stations were considered with a distance of 1km between adjacent stations. Using topographic map and the lattice method these locations were determined on the map. Intersection of grid lines were selected as sampling stations (Fig. 1). The GPS device was used to locate sampling stations (Tiner, 1999).

Sampling strategy and analytical procedures

In order to analyze the chemical and physical factors at each station, samplers were washed 3 times with wetland water. One liter of water was taken from a depth of 30 cm and transported to the laboratory at standard conditions. Nitrate, nitrite, ammonium, alkalinity, hardness, turbidity, conductivity, dissolved oxygen (DO), total dissolved solids (TDS), pH and biochemical oxygen demand (BOD_5) were measured with 3 relications. Mercury thermometer with an accuracy of 0.1°C, Germany oxygen meter (model WTW-OXI 196), Germany Schott Geräte pH meter (model 666 221), American EC meter (model CORNING, CIBA) and turbidity meter (model DRT-15CE) were used for measurement of water temperature, DO, oxygen saturation percentage, pH, EC and turbidity, respectively. Method of remained Oxygen after 5 days using oxygen meter instrument, calorimeter method and optical spectroscopy measurement, using spectrophotometer device: AANALYST 700 PERKIAN ELMER and JENWAY 6400 models were used for measurement of BOD_5, nitrate and nitrite ions respectively (APHA, 1992). Alkalinity was calculated using titration and calorimeter (APHA, 1992). Ammonium and hardness were determined using nesslerization, and titration with EDTA methods, respectively (APHA, 1992). Filtration and drying were performed in order to measure TDS and total suspended solids (TSS) (APHA, 1992).

Statistical analysis

The statistical analysis of data was performed using SPSS 18. Normalization and homogeneity of variances of data were investigated using Kolmogorov–Smirnov and Leven tests. In order to evaluate differences between sampling stations and stages, one-way ANOVA analysis and Duncan test were performed. To show spatial and temporal variations of data, for WQI and water quality variables the linear diagrams and Box and Whisker plot diagrams were used, respectively.

Method of the determination of WQI

WQI was determined based on important human health parameters. Water quality standards to protect aquatics (Canadian Council of Ministers of the Environment) (Lumb *et al.*, 2002; CCME, 2006) and also standards recommended by the World Health Organization (WHO) and Drinking water standards of Iran (WHO, 2004) were used. WQI calculation includes the following steps (Alobaidy *et al.*, 2010):

Step 1:a weight (AW) from 1 to 4, according to the suggestions of experts in previous studies, (Pathak and Banerjee, 1992; Pesce and Wunderlin, 2000; Abrahão *et al.*, 2007; Boyacioglu, 2007b; Dwivedi and Pathak, 2007; Kannel *et al.*, 2007; Chougule *et al.*, 2009;; Karakaya and Evrendilek, 2009) was assigned to each parameter. The mean values of the weights given to each parameter are presented in Table 1. The weight ratios of 1 and 4 were considered as lowest and highest correlations, respectively.

Step 2: relative weight (RW) was calculated using equation 1

equation 1: $RW = AW / \sum AW$

AW: assigned weight to each parameter (based on Table 1). RW: relative weight. The calculated relative weight of each parameter is shown in Table 2.

step 3: using Equation 2 a quality rating scale (Q_i) was assigned for all parameters, except for pH and DO which Equation 3 was used.

Equation 2: $Q_{i} = (C_i / S_i) \times 100$

Equation 3: $Q_{i} = (C_i - V_i / S_i - V_i) \times 100$

C_i: the value of water quality parameter obtained from the laboratory analysis, S_i: The value of water quality parameter reported in world standards or standards of Iran, Q_i: the quality rating. V_i: the ideal value of 7.0 for pH and 14.6 for DO (Alobaidy *et al.*, 2010).

step 4: The sub-indices (SI_i) were calculated for each parameter using equation 4. WQI was estimated using total SI_i (Equation 5), water quality class was determined using Table 3.

Equation 4: $SI_i = RW \times Q_i$

Equation 5: $WQI = \sum SI_i$

Results

Fig. 2 shows WQI changes at the studied stations. WQI was calculated using a set of different parameters and their importance on this index rating. When pollution increased, the amount of numerical index also increased.

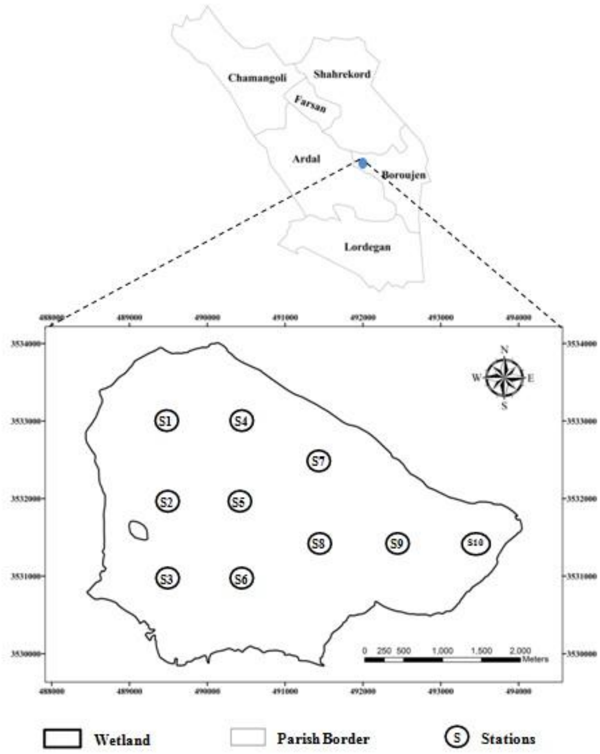


Figure 1: Chaharmahal Bakhtiari and Choghakhor Wetland's map with indication of the study area.

Table 1: Weight assigned to each parameter in different sources and the average proposed in this study.

References	NO_3^- (mg/L)	NO_2^- (mg/L)	NH_4^+ (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Turbidity (NTU)	EC (µs)	TDS (mg/L)	DO (mg/L)	pH	BOD_5 (mg/L)
Abrahão *et al*., 2007	2	2	-	-	1	4	4	-	4	1	3
Boyacioglu 2007	3	-	-	-	-	-	-	-	4	1	2
Chougule *et al*., 2009	-	-	-	3	2	-	4	-	4	4	4
Dwivedi and Pathak., 2007	-	-	-	1	1	2	2	2	4	4	3
Kannel *et al*., 2007	2	2	3	-	1	-	1	2	4	1	3
Karakaya and Evrendilek, 2009	2	2	3	-	1	2	2	-	4	1	3
Pathak and Banerjee., 1992	-	-	-	1	1	2	2	-	4	4	3
Pesce and Wunderlin, 2000	2	2	3	-	1	2	4	2	4	1	3
Proposed mean	2.2	2	3	1.6	1.1	2.4	2.7	2	4	2.1	3

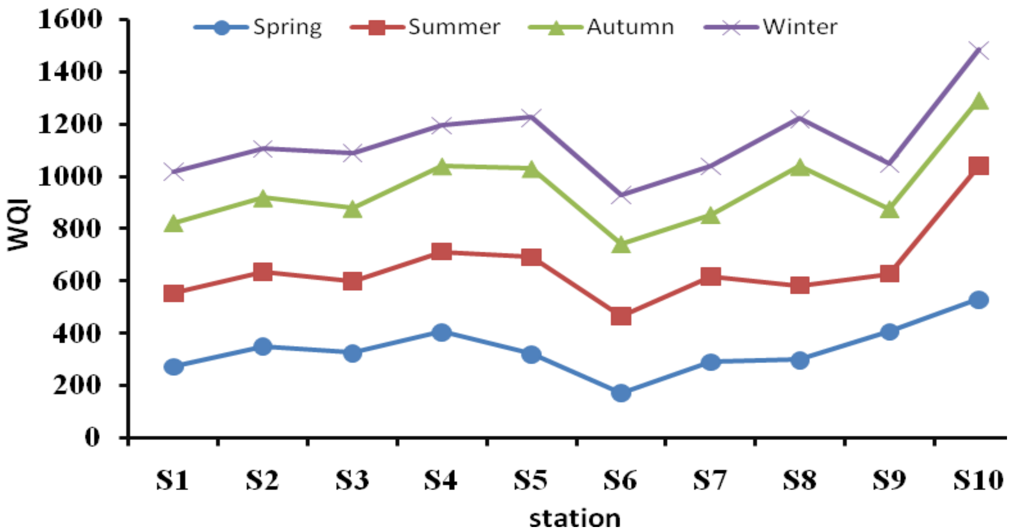


Figure 2: Changes of WQI in the studied stations and the various stages of sampling.

Table 2: Weight ratios of water quality parameters.

parameters	**Water drinking standard (WHO, 2004)**	**Aquatics standard (CCME, 2006; Lumb *et al*,. 2002)**	**Assigned weight**	**Relative weight**
NO_3^- (mg/L)	50	13	2.2	0.084291
NO_2^- (mg/L)	3	0.06	2	0.076628
NH_4^+ (mg/L)	1.5	1.37	3	0.114943
Alkalinity (mg/L)	100	-	1.6	0.061303
Hardness (mg/L)	500	-	1.1	0.042146
Turbidity (NTU)	5	5	2.4	0.091954
EC (µs)	250	-	2.7	0.103448
TDS (mg/L)	500	500	4	0.153257
DO (mg/L)	6.5-8.5	6.5-9	2.1	0.080460
pH	5	-	3	0.114943
BOD_5 (mg/L)	5	5	2	0.076628
Total			26.1	1

Table 3: Water quality classification based on the overall index score (Ramakrishnaiah *et al.*, 2009).

Index values obtained	**Water quality class**
50>	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
300<	Unsuitable

As we can see, WQI was almost uniform and there was no significant difference among different stations (p=0.452). According to Table 3, water quality at stations 4, 5, 7 and 9 was slightly unsuitable and on the border line. Other stations were in the very poor quality class (Fig. 2).
Generally, water quality with an overall average of 283.64 is in the very poor category (Ramakrishnaiah *et al*., 2009) and is diagnosed not proper for human consumption such as drinking.

The change of WQI at different stages are also shown in Fig. 2. The highest value of this index was at stage 4 (late summer) and the lowest at stages 7 and 8 (winter), respectively. In General, there was an upward trend from stages 1 to 4 (spring and summer), and a downward trend from stage 5 to 8 (fall and winter seasons). Significant differences among different stages of sampling (p<0.01), were also observed.

Statistical summary of water quality data in Choghakhor Wetland is given in the Table 4. Also the correlation between WQI and water quality parameters are shown in Table 5. In order to achieve a correct view in relation to factors that have caused undesirable water quality, the results are discussed as follows:

Discussion

The study area WQI quality classification includes three classes of poor, very poor and unsuitable (Ramakrishnaiah *et al*., 2009) which indicates this water resource is not suitable and assured for the public health. Among effective factors, only Dissolved oxygen had the opposite trend with this index. Other factors have a direct relationship with WQI. In cold seasons, effective parameters such as hardness, alkalinity, turbidity and electrical conductivity (EC) increased but BOD_5 and pH decreased in autumn and winter. BOD_5 reduction had a very effective role and class of water quality had changed from unsuitable to very poor in these seasons and to poor in stage 7 (early winter). The reduced BOD_5 was as a result of reduction in agricultural activities and wastewater in autumn.

Changes of water quality variable in various stages of sampling are shown in Fig. 3. The range of pH changes (7.44-10.45), indicated that wetland water was alkaline in nature. pH is one of the most important factors in determining water quality (Ahipathy and Puttaiah, 2006). The average value of pH being 9.12, showed incoherence pH of wetland water with world standards for aquatics (Lumb *et al*., 2002; CCME, 2006), Iran standard, Europe union (Gray, 1996) and also values expressed for surface water which was reported by Li *et al*. (2009) within the range of 6.5 to 8.5 (WHO, 2004). The results showed a positive correlation at the level of 0.01 between the water quality index (WQI) and pH. So that, an increase in pH can lead to declining the Water quality.

Table 4: Statistical summary of water quality data in Choghakhor Wetland.

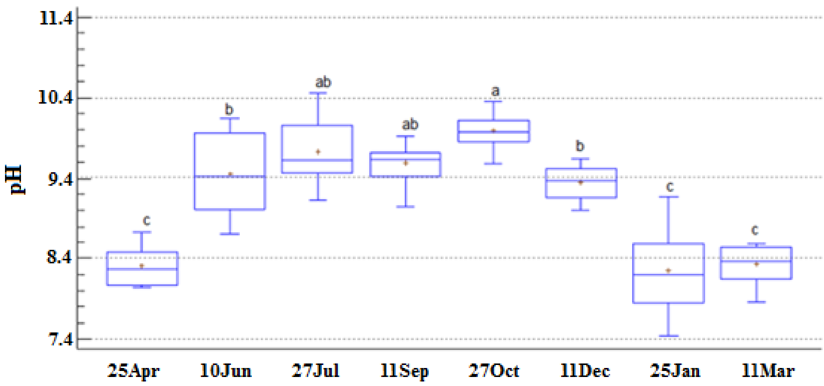
parameters	Minimum	Maximum	Mean	Standard deviation	Standard of Iran
NO_3^- (mg/L)	0.060	0.406	0.195	±0.077	50
NO_2^- (mg/L)	0.007	0.095	0.038	±0.016	3
NH_4^+ (mg/L)	0.036	0.756	0.216	±0.171	1.5
Alkalinity (mg/L)	108	200	140.718	±20.299	-
Hardness (mg/L)	174.157	480.432	314.625	±95.339	-
Turbidity (NTU)	10.712	70.787	26.506	±12.389	5
EC (μs)	202	378	266.337	±37.422	-
TDS (mg/L)	80	393	217.10	±64.70	1500
DO (mg/L)	4.400	14.400	9,317	±2.087	-
pH	7.440	10.450	9.123	±0.752	6.5-9
BOD_5 (mg/L)	9	280	72.587	±51.368	-

Table 5: Pearson correlation coefficients between water quality parameters and WQI

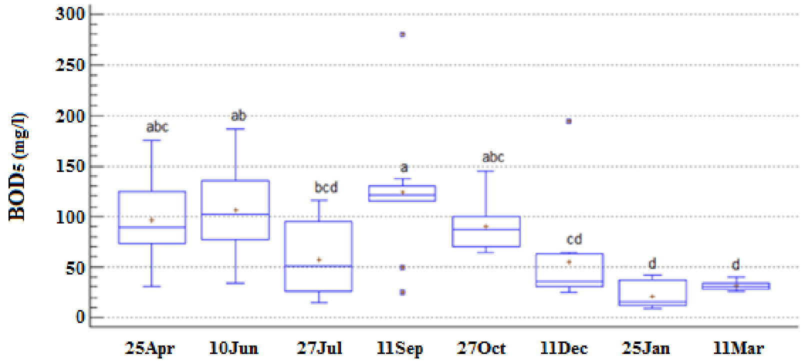
parameters	NO_3^- (mg/L)	NO_2^- (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Turbidity (NTU)	EC (μs)	DO (mg/L)	pH	BOD_5 (mg/L)	NH_4^+ (mg/L)	TDS (mg/L)	WQI
NO_3^- (mg/L)	1											
NO_2^- (mg/L)	0.272^{+}	1										
Alkalinity (mg/L)	-0.216	-0.152	1									
Hardness (mg/L)	0.087	0.254^{+}	0.354^{++}	1								
Turbidity (NTU)	-0.152	0.162	0.271^{+}	0.432^{++}	1							
EC (μs)	0.223^{+}	-0.079	0.551^{++}	0.293^{++}	0.005	1						
DO (mg/L)	-0.002	-0.006	0.072	0.054	0.250^{+}	-0.085	1					
pH	0.250^{+}	0.256^{+}	0.560^{++}	-0.203	-0.385^{++}	-0.259^{+}	0.018	1				
BOD_5 (mg/L)	-0.04	0.031	-0.509^{++}	-0.509^{++}	-0.546^{++}	0.111	0.064	0.352^{++}	1			
NH_4^+ (mg/L)	-0.095	-0.468^{++}	0.074	-0.499^{++}	-0.192	0.073	0.028	-0.151	0.172	1		
TDS mg/L)	-0.095	-0.08	0.390^{++}	0.463^{++}	-0.335^{++}	0.316^{++}	-0.156	-0.219	-0.315^{++}	-0.063	1	
WQI	-0.028	0.093	-0.267^{+}	-0.456^{++}	0.176	0.097	0.083	0.384^{++}	0.980^{++}	0.143	-0.388^{++}	1

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

A



B


BOD5 (mg/l)
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250
200
150
100
50
0
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ab
bcd
a
abc
cd
d
d
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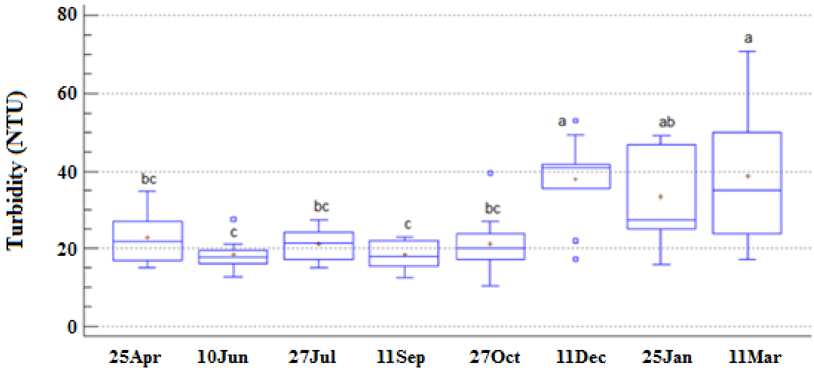
10Jun
27Jul
11Sep
27Oct
11Dec
25Jan
11Mar

C


Turbidity (NTU)
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60
40
20
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bc
c
bc
c
bc
a
ab
a
25Apr
10Jun
27Jul
11Sep
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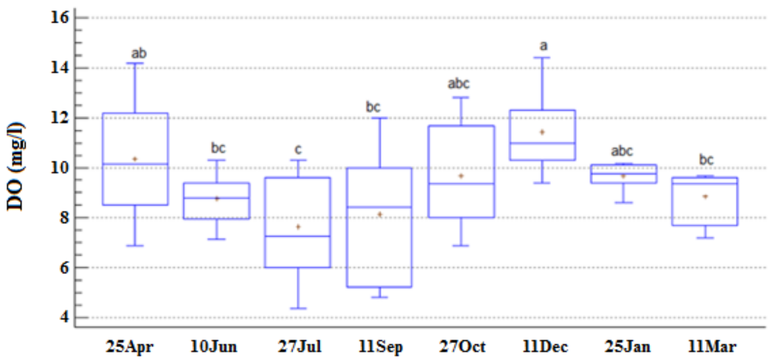
11Dec
25Jan
11Mar

D


DO (mg/l)
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14
12
10
8
6
4
ab
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c
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abc
a
abc
bc
25Apr
10Jun
27Jul
11Sep
27Oct
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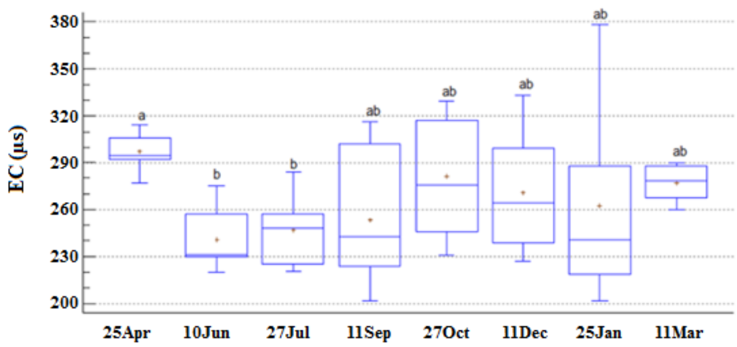
25Jan
11Mar

E


EC (µs)
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320
290
260
230
200
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b
b
ab
ab
ab
ab
ab
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11Sep
27Oct
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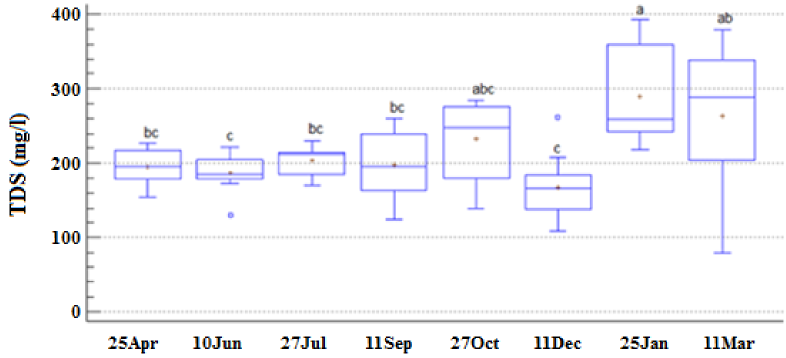
F


TDS (mg/l)
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300
200
100
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bc
c
bc
bc
abc
c
a
ab
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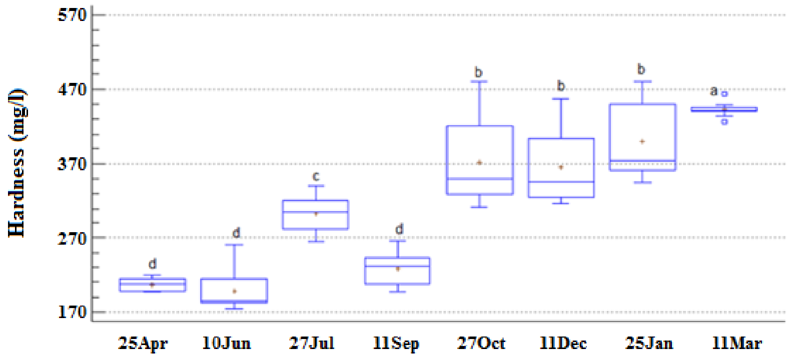
11Sep
27Oct
11Dec
25Jan
11Mar

G


Hardness (mg/l)
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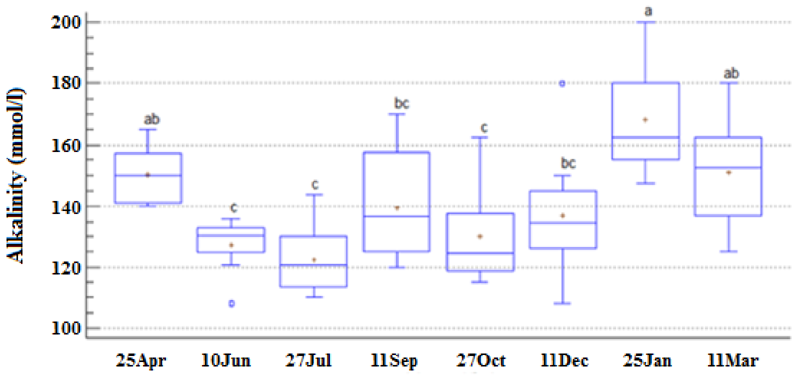
470
370
270
170
d
d
c
d
b
b
b
a
25Apr
10Jun
27Jul
11Sep
27Oct
11Dec
25Jan
11Mar

H


Alkalinity (mmol/l)
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160
140
120
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c
c
bc
c
bc
a
ab
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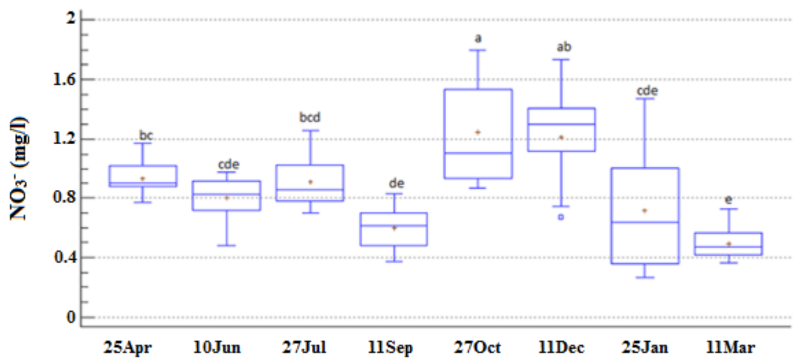
11Sep
27Oct
11Dec
25Jan
11Mar

I


NO_3^- (mg/l)
2
1.6
1.2
0.8
0.4
0
bc
cde
bcd
de
a
ab
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11Dec
25Jan
11Mar

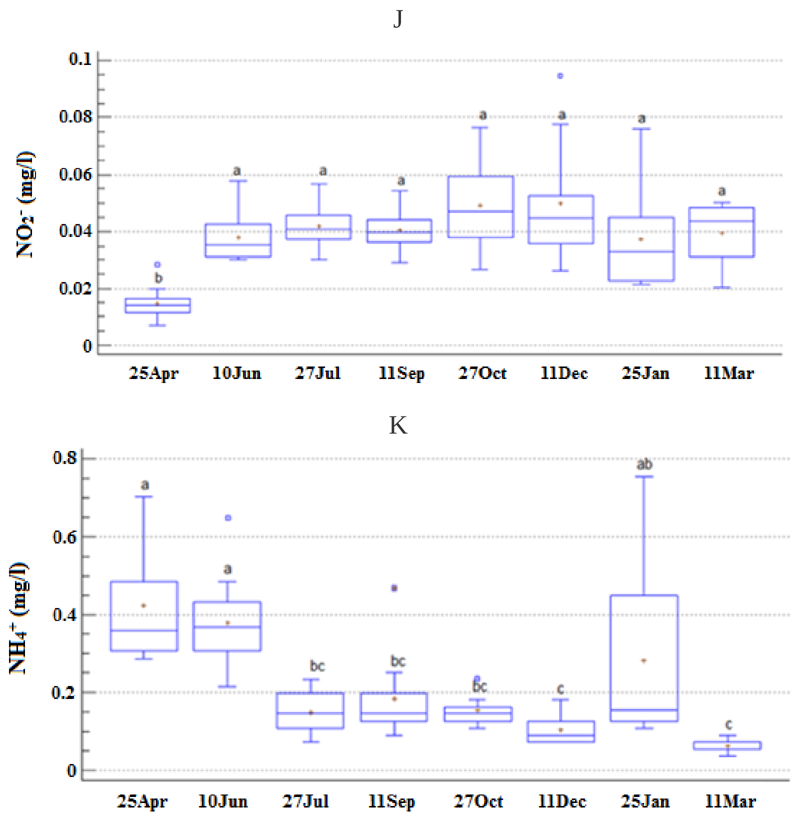

Figure 3: Changes of water quality variable in the various stages of sampling. (A) pH, (B) Biological oxygen demand, (C) Turbidity, (D) Dissolved oxygen, (E) Electrical conductivity, (F) Total dissolved solid, (G) Hardness, (H) Alkalinity, (I) Nitrate, (J) Nitrite, (K) Ammonium.

BOD_5 with the average of 58.72 mg per liter was much higher than the world and Iran standards (WHO, 2004) and reached to a critical state. According to the fact that, non-polluted waters are likely to have a BOD_5 value less than 3 mg per liter, it Seems that BOD_5 is the most important and effective parameter in calculating water quality index (WQI) and high numerical index for this area, indicated that it had played a decisive role. BOD_5 values can be due to entering pollutions from human activities including fishing, tourism around the wetland or pollutions of local sources (rural, agricultural, etc.) (Kazi *et al.*, 2009). So BOD_5 level shows possible organic pollution in this area and careful assessment of wetland needs to a long-term monitoring. The highest correlation between water quality parameters and WQI index at the level of 1% was related to this factor, which was reflected in its effective role in water quality index.

Turbidity is also another important factor in calculating the WQI index and suitability of water quality for human consumption and other users. In this research turbidity had been in second place of importance after BOD_5 and it is one of the factors that lead to worsen the conditions. Calculated turbidity was beyond limit and did not match with aquatics standards (Lumb *et al.*, 2002; CCME, 2006), Europe union (Gray, 1996) and also world and Iran standards (WHO 2004). Of course it is noteworthy that lack of correlation between this factor with WQI index was the reason of reduction in the index value at cold seasons despite the increase in turbidity. In spite of the fact that turbidity raised up, BOD_5 reduction played more effective role and it was able to reduce WQI.

The amount of TSS in wetland water was high, like turbidity. A significant increase in TSS levels was observed especially in autumn and winter. Based on the provided standards, the allowable amount of suspended solids, wetland water quality was not suitable for human consumption (drinking, swimming, etc.), aquaculture and also various utilizations such as agriculture and industry (Lumb *et al.*, 2002; Hammer, 1986).

Dissolved oxygen, during the study never, reached to the critical conditions and water quality was good. As seen the average of dissolved oxygen concentration was equal to 9.31 mg per liter that matched with the Canadian aquatics standard (Lumb *et al.*, 2002; CCME, 2006), world standard (WHO, 2004) and was suitable for human consumption (swimming, bathing and drinking) and many aquatic organisms (Hammer, 1986; Wilcock *et al.*, 1995). Dissolved oxygen was high in all the stations and stages of sampling. One of the reasons could be the presence of aquatic plants and photosynthesis (Li *et al.*, 2009). These results showed a good match with results from other studies (Nemati Varnosfaderany *et al.*, 2009; Alobaidy *et al.*, 2010).

The importance of EC was because of the positive ions that had many effects on the taste of water. So it has considerable effects on the acceptability levels of water for drinking (Pradeep, 1998; WHO, 2004). EC is an indirect result of the amount of dissolved salts. High EC can be caused by natural atmospheric factors, certain sedimentary rocks or a human source such as industrial or sewage output (WHO, 2004). The observed changes in the rate of EC should be caused by changing the concentration of dissolved salts. About Choghakhor Wetland, that can be affected by the input currents ,turbulences in the water and mixing of bed sediments due to the shallow wetland which caused by seasonal winds. The results showed that EC levels were somewhat higher than reported EC by the World Health Organization (WHO, 2004). But levels of this factor were much lower than the standard provided by the Europe Union (Gray, 1996).

Generally, TDS changes were similar to the EC. The EC increased along with the increase in dissolved solids (mostly salts). It’s seems that strong wings, severe turbulences in water and mixing of bed sediments also can increase TDS value in fall and winter. The calculated TDS in this research was in accordance with the world and Iran standards (WHO, 2004) and was less than the limit. That was suitable for human consumption (swimming, bathing, tourism, drinking), aquaculture and also agriculture and industry (Hammer, 1986).

Water hardness is another important parameter for waters quality used for domestic, industrial, agricultural and aquaculture consumptions. Results obtained in this study have shown that the water hardness was often higher than the minimum reported by the World Health Organization (200 mg per liter) (WHO, 2004). According to standard of Iran (500 mg per liter) the reported hardness was suitable and less than the standard level in Iran.

Alkalinity was higher than the reported limits in world health organization and Iran standards (WHO, 2004). When hardness and alkalinity rates grew, water pollution and WQI index also increased, but as seen, there was a negative correlation between these factors and WQI index which was due to the reduction in WQI index in cold seasons. BOD_5 decline was the reason for the WQI reduction.

The average amounts of nitrate and nitrite in wetland water was 0.865 and 0.038 mg per liter respectively which was the lowest amount of nitrogen compounds in the wetland. Their values was consistent with the world and Iran standards (WHO, 2004), European Union standard (Gray, 1996) and also aquatics standards (Lumb *et al.*, 2002; CCME, 2006). Therefore the nitrate and nitrite content of the wetland water was suitable for aquaculture, drinking and other purposes. One reason for the low levels of nitrate and nitrite was the vegetation because the inorganic nitrogen compounds could be absorbed by the plants (Li *et al.*, 2009).

The most abundant form of nitrogen compounds, after nitrate, was ammonium. The average amount of ammonium was 0.216 mg per liter. The amount of ammonium, like other compounds of nitrogen, was in the range of the world and Iran standards (WHO, 2004), the Union of Europe (Gray, 1996) and also aquatics standards (Lumb *et al.*, 2002) which is suitable for human usages.

The WQI index, has revealed that the wetland water quality is not good for public health and drinking purposes. The addition of organic pollutants, as well as the people and tourism activities waste in the region were the most effective factors that could lead to the reduction of water quality. Long-term and continuous monitoring should be implemented in order to obtain better results. Finally, the cooperation of relevant authorities can lead to better management and the health of this ecosystem.

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