Spatial–temporal variability in water quality in Ghareh-chai River, Golestan Province, Iran

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Abstract. We present a spatio-temporal evaluation of modified water quality index ($IRWQI_{SC}$) in Ghareh-chai River, Golestan Province, Iran. Water quality parameters were measured monthly from 8 stations along the river from October 2015 to September 2016. Annual $IRWQI_{SC}$ varied from 55.5 to 31.46 showing spatial fairly good to fairly poor water quality. Temporal variation of the annual $IRWQI_{SC}$ showed the river water quality had the best and worst condition in autumn (average = 53.69) and summer (average = 27.90) respectively. The first station after the spring was classified from fairly good (65.40-61.60) to average (51.25-50.34) during the year showing the best condition. Trout farms, avicultures, agriculture, mining, urban and domestic waste water discharges were the major pollutant resources. The last station after Ramian city received all the discharges and had the worst condition (46.93-32.27) during the year. According to the results, Ghareh-chai River has a fairly poor water quality (36.61). Since there was not enough distance between different avicultures, trout farms and other pollutant resources, the river self-purification was not enough to remove all the pollution. The river experienced more stress in summer due to decreasing water volume and receiving agricultural waste waters. It seems urgent protective action and policy should be taken based on environmental standards to avoid future risks.
Key Words: Ghareh-chai River, $IRWQI_{SC}$, pollution, spatio-temporal variation, water quality.

Introduction. Rivers carry the one way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources (Shrestha & Kazama 2007). They have variety of functions such as water supply, irrigation, power generation, shipping, and sightseeing, hence playing an important role in people's living and agricultural production (Pan et al 2015).

During the last decades, the combination of rapid population growth and of industrialization and urbanization processes has increased the pressure placed on water resources (Balderas et al 2016) and human beings have been focusing on the exploration of the economic function from rivers (Pan et al 2015). In addition to, the extent of climate changes affect significantly water supply and patterns of water demand (Vörösmarty et al 2000), while the river water quality being simultaneously exacerbated (World Water Assessment Programme 2009; Schwarzenbach et al 2010; Törnqvist et al 2011; Yen et al 2012) by human interventions, such as hydrological alterations (Booker & Woods 2014), land use change (Seeboonruang 2012), inputs of toxic chemicals and nutrients (Gevrey et al 2010), and changes in other physicochemical properties of water (Paul & Meyer 2001; Vanlandeghem et al 2012) which cause different environmental problems, for example shortage of drinking water (Bao et al 2012), threatens aquatic biodiversity (Vörösmarty et al 2010), deterioration of aquatic ecological systems (Hu & Cheng 2013), emergence of endemic diseases (Schwarzenbach et al 2010; Zhao et al 2012), and diminishes the related social and economic benefits (Hazilla & Kop 1990). That is why the quality and quantity of available water resources have become a serious issue and cause a lot of concern for the public and the government. Therefore, it is imperative to have reliable information on characteristics of water quality for sustainable water resources management and safe guarding the public health (Jung et al 2016; Sun et al 2016). Moreover, understanding and quantitatively evaluating the trend of spatial and temporal variations of river water quality are indispensable for efficient management of water resources (Wang et al 2015).

Different water quality evaluation methods have been developed. The traditional monitoring approaches are predominantly conducted by measuring physical and chemical parameters (e.g., stream flow, pH, nitrate, biochemical oxygen demand). Although these parameters provide information about water pollution (USEPA 2013), some of these require expensive laboratory analyses. Moreover, the methods are based on comparisons of the determined variables with the local normative standards, which provide partial information on the overall quality (Pesce & Wunderlin 2000). Some studies have applied statistical technique such as the principal component analysis, which can aid in identifying natural or anthropogenic factors that can cause alterations in water quality (Vialle et al 2011; Selle et al 2013; Vonberg et al 2014). In order to rapidly and easily obtain the information of freshwater quality with a global vision, the National Sanitation Foundation (NSF) developed a comprehensive index methods, the water quality index (WQI) (Ott 1978), and then several modified water quality indices have been developed based on this method (Nasiri et al 2007). WQI is a mathematical method, transforming large quantities of water quality data into a single number that represents general quality of surface water quality (Srebotnjak et al 2012). It is proved that WQI is indeed a practical method considering critical environmental variables which represent the pollution conditions in water body (Simões et al 2008). Moreover, WQI can facilitate comparisons between different sampling sites and identify the changing trends of water quality. However, the calculation of WQI has been developed with different methods. Generally, similar physical-chemical variables are considered, but the statistical integrations of variables are different among these methods in different reports. In fact, modified WQI is necessary in order to reduce the redundant variables and decrease the analytical cost. Moreover, the establishment of specific WQI should take into account local background conditions, such as changes of land use or anthropogenic activities (Debels et al 2005). That is why Iranian Organization of Environmental Protection modified water quality index $IRWQI_{SC}$ (Iran Water Quality Index for Surface Water Resources-Conventional Parameters) based on local condition and applied it to provide information and better understanding the overall water quality condition of surface water resources in Iran.

Ghareh-chai River with a length of 35.8 kilometers is one of the branches of the Gorgan-Rud River (Golestan, Iran). The maximum average discharge of water in Ghareh-chai River is as high as 5.8 m^3 s^{-1} in spring and the minimum is 0.3 m^3 s^{-1} in summer. It is one of most seriously affected rivers by human activities. Urban and agricultural areas are widespread in the basin, and many non-point and point source pollutants input into the river (Table 1, Figure 1). Ramian city, located in the lower reaches of Ghareh-chai River, is an important city discharging the waste water into the river. Also agriculture activities have been developed in the flood plains, and cause a lot of water quality problems, such as high nitrogen and phosphorus concentrations. Nevertheless, the pollution sources of the Ghareh-chai River are seldom explored. Furthermore, the spatial-temporal variations and trends of water quality in the Ghareh-chai River have not been fully investigated. Therefore, in this study we selected Ghareh-chai River to use $IRWQI_{SC}$ as indicator of water quality to study on its spatial and temporal variations

Material and Method

Site sampling and water quality parameter. This study was carried out in Ghareh-chai River located in the eastern Elburz Mountains at 55^{o}02'24'' to 55^{o}16'47'' E and 36^{o}48'26'' to 37^{o}03'05'' N. To characterize the spatial and temporal variability of water quality and the effect of human activity on the water quality along the river basin, location of eight sampling sites were carefully selected. The water was sampled seasonally from October 2015 to September 2016 (Figure 1).

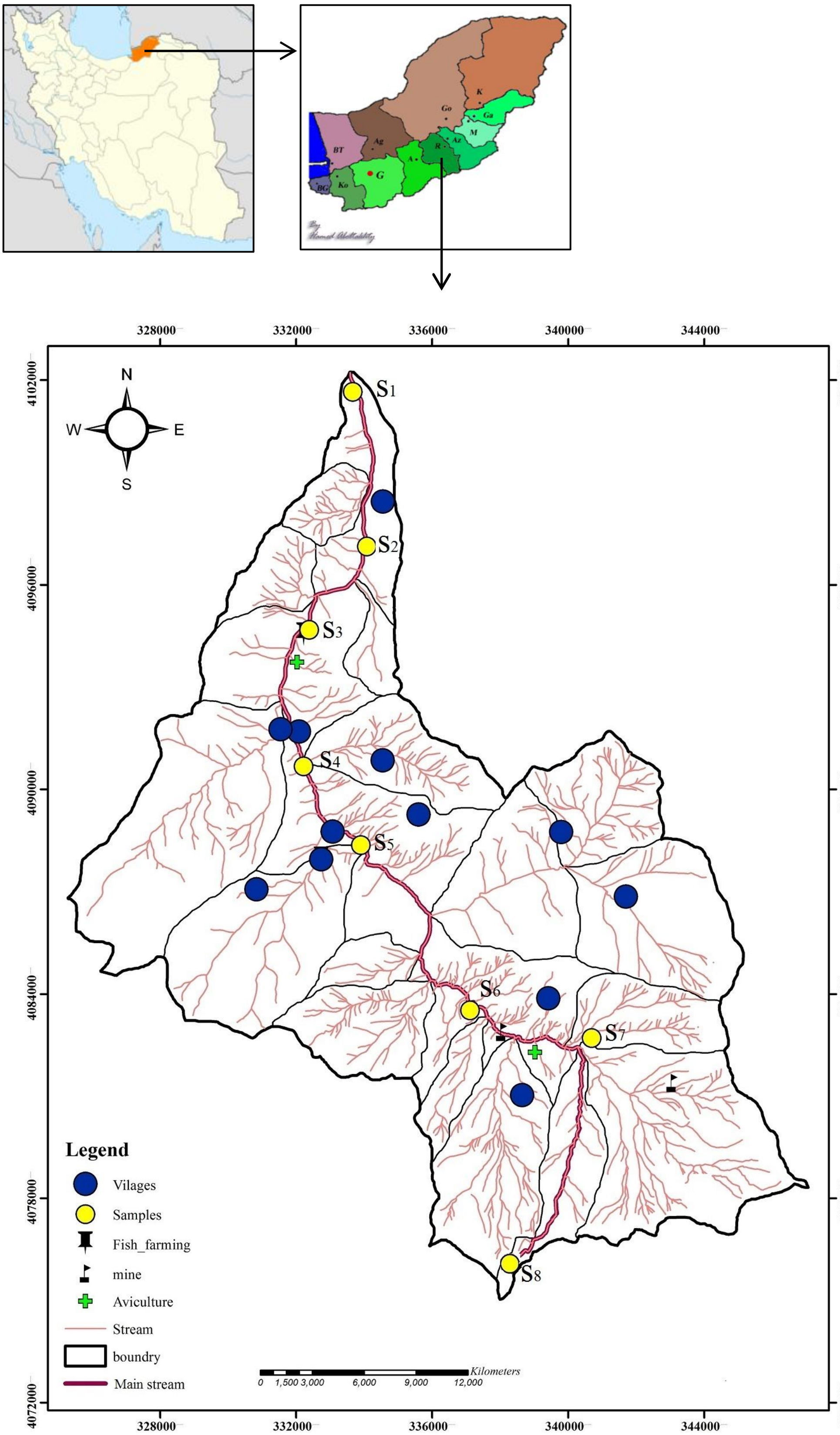

Figure 1. Sampling sites (yellow circles) in the Ghareh-chai River.

Different types of water quality parameters including temperature (Tem, °C) turbidity (Turb, NTU), total hardness (Hard, ppm), electrical conductivity (EC, µmos cm^{-1}), phosphate (PO_4^{3-}, ppm), nitrate (NO^{3-}, ppm), ammonium (NH^{4+}, ppm), pH, dissolved oxygen (DO, saturated percent and ppm), biological oxygen demand (BOD_5, ppm), chemical oxygen demand (COD, ppm) and fecal coliforms (Fecal, MPN/100 mL) were measured by water checker u-10 and spectrophotometer.

Table 1

Pollutant point source along Ghareh-chai River

Pollutant source	*Wastewater type*	*Population*	*Actual capacity*
Coal mine 1	Mine/Industrial	-	1000 ton/month
Village (Viro)	Domestic	953	-
Village (Kashkak)	Domestic	865	-
Trout farm 1	Aquaculture	-	45000 kg $year^{-1}$
Aviculture 1	Agriculture	-	20000 chickens
Village (Ghareh Chai)	Domestic	359	-
Trout farm 2	Aquaculture	-	45000 kg $year^{-1}$
Aviculture 2	Agriculture	-	20000 chickens
City (Ramian)	Urban	12263	-
Village (Bagher Abad)	Domestic	277	-
Village (Seyed Kalateh)	Domestic	174	-
Village (Pol e Aram)	Domestic	23	-
Village (Pa Ghaleh)	Domestic	179	-
Village (Alhadi)	Domestic	63	-
Village (Razi)	Domestic	182	-
Village (Shesh Ab)	Domestic	83	-
Coal mine 2	Mine/Industrial	-	1000 ton $month^{-1}$
Aviculture 3	Agriculture	-	20000 chickens

Water quality index. $IRWQI_{SC}$ was calculated using the following equation:

$$IRWQI_{SC} = \left[\prod_{t=1}^{n} I_t^{W_t}\right]^{\frac{1}{\gamma}}, \ \gamma = \sum_{i=1}^{n} W_i$$

Where n represents the total number of parameters, I_t is the normalization value assigned to parameters in the 0-100 scale, and W_t equals the coefficient of each water quality parameter (Table 2).

Table 2

Water quality parameters and their coefficient used in $IRWQI_{SC}$

Parameter	*Unit*	*Coefficient*
Fecal coli form	MPN/100 mL	0.140
BOD_5	ppm	0.117
NO_3^-	ppm	0.108
Dissolved oxygen	Saturation (%)	0.097
Electrical conductivity	μmos cm^{-1}	0.096
COD	ppm	0.093
NH_4^+	ppm	0.090
PO_4^{3-}	ppm	0.087
Turbidity	NTU	0.062
Total hardness	ppm $CaCo_3$	0.059
pH	---	0.051

For each site, one annual and four seasonal $IRWQI_{SC}$ values were determined. To calculate WQI of each season at a given site, average parameter values were calculated from the data obtained by using the data from April to June, July to September, October to December, and January to March, respectively. Values from all four seasons were averaged for calculating the annual $IRWQI_{SC}$. The $IRWQI_{SC}$ is a no unit number ranging from 1 to 100, in range of scoring 85-100 is excellent, 70-85 is good, 55-70 is fairly good, 45-55 is medium, 30-45 fairly poor, 15-30 is poor, and 0-15 is very poor. The higher the number is, the better quality of water is.

Data analysis. Data were checked for normality distribution with the Kolmogorov-Smirnov test. Spatial and temporal variations of water quality parameters were analyzed using one-way ANOVA and Duncan's post-hoc test, assuming a significant level of α = 0.05.

Results and Discussion

Water quality parameters. Data on water quality parameters of Ghareh-chai River are given in Table 2. The station 1 is the first station after spring and also it is not exposed to the pollution sources, so it is considered as the test station. According to Table 3, most of the parameters showed no significant differences between stations except for fecal coliform, turbidity, and pH, as they increased significantly along the river ($p \leq 0.05$). BOD_5 increased gradually along the river, and the maximum annual value was measured in station 8. The water contained more than 3.8 ppm by dissolved oxygen during the year. The nitrate, ammonia and phosphate concentrations varied between 0.89-2.35, 0.27-0.73, and 0.43-0.63 ppm, respectively. The maximum values were measured in station 8. COD showed a biphasic trend in different stations and changed from 51.24 (station 1) to 152.83 (station 8) ppm. The maximum electrical conductivity and total hardness were 616.75 µmos cm^{-1} and 105.35 ppm which measured at station 4 and 8, respectively.

Table 3

Mean values of water quality measurement along the Ghareh-chai River

Parameters	*Station*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Log Fecal	0.95^{a} ± 0.48	1.45^{ab} ± 0.4	1.92^{bc} ± 0.39	2.37^{cd} ± 0.53	2.64^{de} ± 0.38	2.77^{de} ± 0.24	3.04^{e} ± 0.02	3.04^{e} ± 0
BOD_5	2.81 ± 0.24	2.94 ± 0.47	3.12 ± 0.57	3.08 ± 0.58	3.01 ± 0.44	3.10 ± 0.46	3.17 ± 0.53	3.23 ± 0.37
NO_3^-	0.89 ± 0.59	1.53 ± 1.41	1.97 ± 1.69	1.98 ± 1.57	2.28 ± 1.92	2.31 ± 0.67	2.32 ± 0.22	2.35 ± 0.3
DO	4.84 ± 1.43	4.74 ± 1.38	4.15 ± 1.28	4.24 ± 1.01	4.24 ± 1.04	3.83 ± 0.41	3.9 ± 0.22	3.81 ± 0.45
EC	487.63 ± 32.19	493.75 ± 76.38	510.5 ± 118.9	616.75 ± 283.18	472.63 ± 28.81	495.17 ± 100.11	515.33 ± 92.06	566.5 ± 99.63
COD	51.24 ± 22.27	95.31 ± 89.1	76.18 ± 29.4	81.64 ± 32.7	76.33 ± 33.76	144.83 ± 57.47	145.67 ± 55.6	152.83 ± 59.08
NH_4^+	0.27 ± 0.18	0.49 ± 0.42	0.61 ± 0.49	0.62 ± 0.47	0.71 ± 0.57	0.72 ± 0.25	0.72 ± 0.23	0.73 ± 0.29
PO_4^{3-}	0.43 ± 0.32	0.46 ± 0.4	0.44 ± 0.28	0.45 ± 0.21	0.59 ± 0.39	0.58 ± 0.07	0.61 ± 0.07	0.63 ± 0.12
Log Turb	2.4^{a} ± 0.44	2.46^{a} ± 0.37	2.60^{ab} ± 0.31	2.56^{ab} ± 0.32	2.54^{ab} ± 0.4	2.7^{ab} ± 0.47	3.55^{b} ± 0.89	3.58^{b} ± 0.71
Hard	64.09 ± 63.1	70.64 ± 65.95	80.96 ± 80.36	81.65 ± 80.92	84.44 ± 72.28	99.75 ± 80.63	101.48 ± 79.17	105.35 ± 76.06
pH	7.5^{a} ± 0.24	7.76^{ab} ± 0.29	7.98^{ab} ± 0.25	8^{ab} ± 0.31	7.99^{ab} ± 0.37	8.08^{b} ± 0.32	8.10^{b} ± 0.41	8.14^{b} ± 0.26
Temp	12.68 ± 6.47	14.66 ± 6.04	17.48 ± 8.63	19.94 ± 9.06	21.13 ± 9.98	24.4 ± 1.86	24.8 ± 1.21	25.02 ± 1.49

Data presented as mean ± standard deviation. Different letter shows p ≤ 0.05. Note: temperature (Tem, °C) turbidity (Turb, NTU), total hardness (Hard, ppm), electrical conductivity (EC, µmos cm-1), phosphate (PO43-, ppm), nitrate (NO3-, ppm), ammonium (NH4+, ppm), pH, dissolved oxygen (DO, saturated percent and ppm), biological oxygen demand (BOD5, ppm), chemical oxygen demand (COD, ppm) and fecal coliforms (Fecal, MPN/100 mL).

Water quality parameters of warm seasons (spring and summer) are summarized in Table 4 and Figure 2. Most of the parameters increased in summer including temperature, pH, coliform, electrical conductivity, biological oxygen demand, nitrate, ammonia and phosphate, while some others such as dissolved oxygen and hardness decreased. The chemical oxygen demand (except in station 2) and turbidity did not show many variations. The biological and chemical oxygen demand, nitrate, ammonia, and phosphate showed biphasic trend from up to downstream in both spring and summer. They varied between 2.41-2.96, 42.71-153, 0.71-2.25, 0.27-0.63, and 0.19-0.63 ppm in spring and 3.5-3.9, 60-224.13, 1.8-5.16, 0.56-1.61, and 0.89-1.16 ppm in summer respectively. However the coliform showed an increasing trend. It reached from 14.5 (spring) or 50 (summer) to > 1100 MPN/100 mL. In summer, in the river was no water after station 5, so no water sample and data were obtained for these stations.

Table 4

Water quality parameters along the Ghareh-chai River in spring and summer

Station	*Season*	*Log Fecal*	*EC*	*COD*	*Log Turb*	*Hard*	*pH*	*Temp*
1	Spring	1.13	447.5	42.71	1.98	107.12	7.36	14
	Summer	1.7	526	60	1.81	10	7.65	21.3
2	Spring	1.4	445.5	48.86	2.1	122.89	7.48	15.2
	Summer	2	603	224.13	2	11.3	7.8	23
3	Spring	2.07	446.6	87.07	2.45	140.01	7.85	17.35
	Summer	2.4	679	81.63	2.26	14.2	8.22	29.7
4	Spring	2.5	468	95.93	2.28	144.15	7.91	20.25
	Summer	3.04	1041	74	2.2	9.8	8.3	32.5
5	Spring	2.85	445.5	77.93	2.17	125.07	7.93	21.95
	Summer	3.04	499	67.88	2	9	8.35	34.8
6	Spring	2.66	397	145	2.07	155.22	8.25	14.1
7	Spring	3	388	140	2.3	152.34	8.23	14.2
8	Spring	3.04	374	153	2.96	145.44	8.19	14.6

Note: temperature (Tem, °C) turbidity (Turb, NTU), total hardness (Hard, ppm), electrical conductivity (EC, μmos cm^{-1}), chemical oxygen demand (COD, ppm) and fecal coliforms (Fecal, MPN/100 mL).

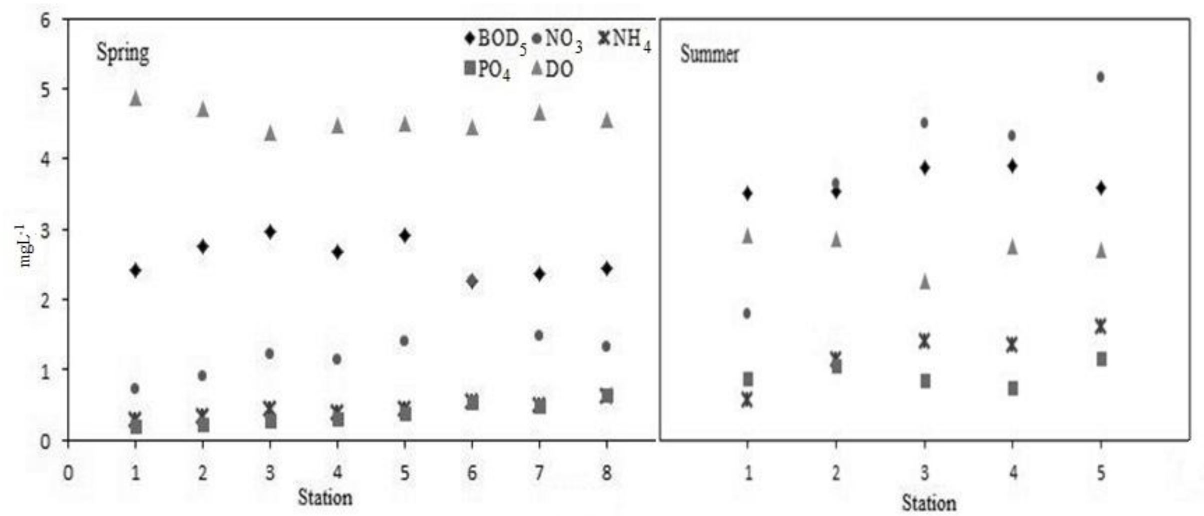

Figure 2. Concentrations of NO_3, NH_4, PO_4, DO and BOD_5 along the Ghareh-chai River in spring and summer.

Water quality parameters of cold seasons (autumn and winter) are summarized in Table 5 and Figure 3. Most of the parameters were higher in winter including coliform, turbidity, dissolved oxygen, hardness, biological and chemical oxygen demand, nitrate, ammonia and phosphate, while the temperature was lower and the electrical conductivity did not show much variation.

The coliform, nitrate, ammonia, and chemical oxygen demand showed an increased trend from up to downstream in autumn. They varied between 3 to > 1100 MPN/100 mL, 0.3-1.25, 0.1-0.39, and 25.25-45 ppm in autumn. However the biological oxygen demand (2.45-2.8 ppm) and phosphate (0.28-0.4 ppm) showed biphasic trend and dissolved oxygen (3.9-5.27 ppm) decreased along the river.

In winter, coliform, ammonia, biological and chemical oxygen demands measured in downstream were higher. The nitrate and phosphate showed biphasic trend as the maximum values were 2.4 ppm and 0.51 ppm measured in station 6 respectively. In winter, the river was floody. The maximum and minimum turbidity were 646 and 10000 NTU measured at the first and the last stations, respectively.

Table 5

Water quality parameters along the Ghareh-chai River in autumn and winter

Station	*Season*	*Log Fecal*	*EC*	*COD*	*Log Turb*	*Hard*	*pH*	*Temp*
1	Autumn	0.48	485	25.25	2.30	10	7.5	8
	Winter	0.54	492	77	2.81	129.22	7.5	6.35
2	Autumn	1.04	437	25.25	2.36	16	7.6	9.7
	Winter	1.37	489.5	83	2.84	132.38	8.15	6.17
3	Autumn	1.59	411	34	2.38	9.3	7.7	10.7
	Winter	1.6	505.5	102	2.96	160.31	8.16	5.02
4	Autumn	1.81	463	40	2.42	8.8	7.6	11.8
	Winter	2.12	495	116.5	2.93	163.85	8.19	5.02
5	Autumn	2.18	450	39	2.45	7.8	7.5	12.1
	Winter	2.49	496	120.5	2.93	155.89	8.17	4.96
6	Autumn	2.38	594	39	2.54	8.9	7.7	12.7
	Winter	2.85	464.5	130.5	3.02	140.765	8.28	4.77
7	Autumn	3.04	571	41	2.64	8.7	7.7	14.1
	Winter	3.04	497	135.5	4	138.215	8.45	5.11
8	Autumn	3.04	572	45	2.65	7.5	7.8	13.8
	Winter	3.04	435.5	140.5	4	131.885	8.31	4.77

Note: temperature (Tem, °C) turbidity (Turb, NTU), total hardness (Hard, ppm), electrical conductivity (EC, µmos cm^{-1}), chemical oxygen demand (COD, ppm) and fecal coliforms (Fecal, MPN/100 mL).

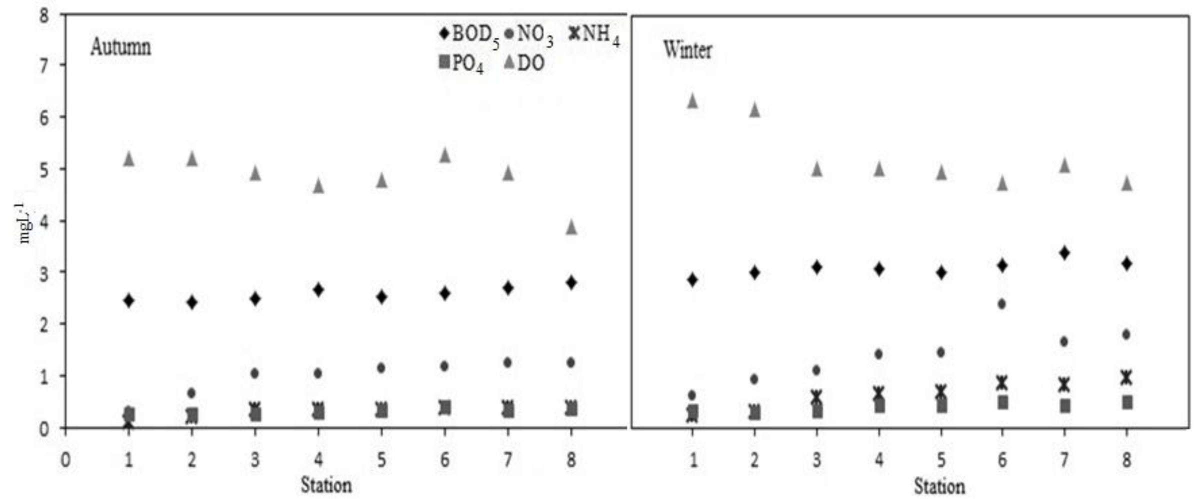

Figure 3. Concentrations of NO3, NH4, PO4, DO and BOD5 along the Ghareh-chai River in autumn and winter.

$IRWQI_{SC}$ index. The calculation results of $IRWQI_{SC}$ from different seasons and annual were shown in Figure 4. The $IRWQI_{SC}$ analysis enabled to classify the river water as: first station as fairly good ($IRWQI_{SC}$ = 55.5), upstream stations 2 and 3 as medium ($IRWQI_{SC}$ = 46.73 and 47.91 respectively), midstream station 4 and 5 as fairly poor ($IRWQI_{SC}$ = 44.12 and 42.31 respectively) and the downstream stations including 6-8 classified as fairly poor ($IRWQI_{SC}$ = 35.86, 31.86, and 31.46, respectively).

Water quality showed better condition in autumn as the $IRWQI_{SC}$ varied from 65.4 (fairly good) to 46.93 (medium) along the river, while the water has the worst condition in summer. The $IRWQI_{SC}$ reached form 50.34 (medium) to 36.23 (fairly poor) from upstream (station 1) to midstream (station 5). The mean value of $IRWQI_{SC}$ classified river water as medium (45.52), poor (27.90), medium (53.69), fairly poor (37) for spring, summer, autumn, and winter respectively. The overall $IRWQI_{SC}$ was calculated 36.61 (fairly poor) for the Ghareh-chai River.

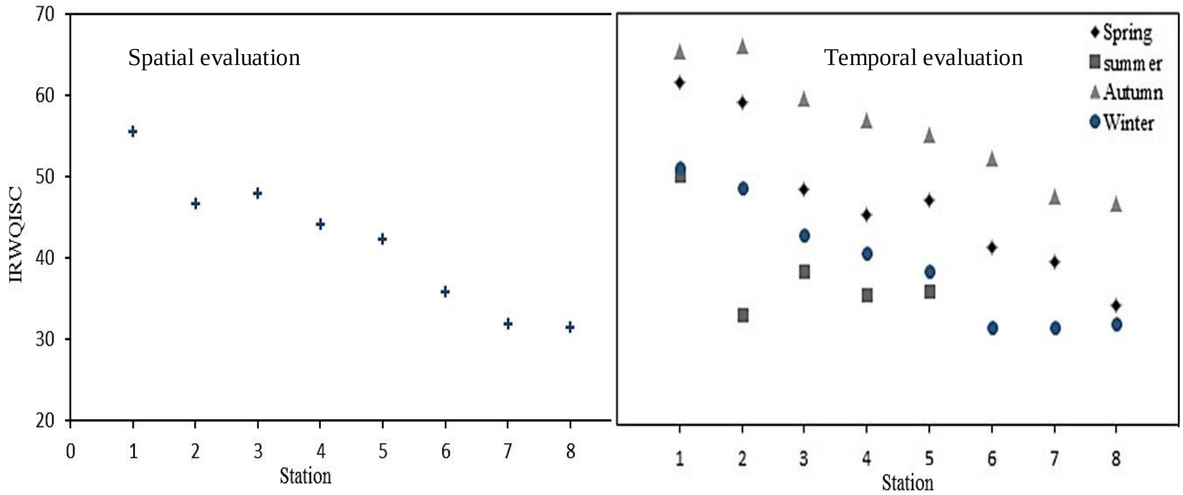

Figure 4. Spatial and temporal evolution of $IRWQI_{SC}$ in Ghareh-chai River.

It is not an easy task to evaluate the overall water quality by analyzing separate variables, especially different criteria for different uses. Water quality index assembles data from several regular water quality parameters and provides a value (similar to a score) with a fast and understandable explanation of water quality in the specific area and time (Hoseinzadeh et al 2015). Moreover, WQI may help us to decide the overall water quality for the quick evaluation of environmental impact (Sun et al 2016).

In Iran, most of the studies on evaluation of water quality were carried out based on different methods and similar indices were not used to analyze water quality. Therefore the decision makers have suffered from the lack of local water quality standard. Developing a new index by Iranian Organization of Environmental Protection would help the managers to compare quality of different water resources and have a comprehensive sight.

In this study we evaluated spatial and temporal variations of water quality using the $IRWQI_{SC}$. In general, based on $IRWQI_{SC}$ results the river water quality classified as the fairly poor. Previous studies confirmed that land use is a key component in water quality determination causing a decrease in water quality (Wuta et al 2015). The river actually received different type of waste waters such as agricultural, industrial, and urban/domestic discharges. As it was shown in Figure 1, there are three livestock units, two trout farms, and two coal mines in this catchment area.

The analysis of WQI also indicates whether different aquatic species are able to survive in related water quality class (Carbajal-Hernández et al 2012). Also it is a guideline to identify the water restrictions (Abbasi & Abbasi 2012). According to water quality classification, water ranged in fairly poor and poor class is suitable for supporting limited taxa. However it does not support drinking and recreational usage, but it could be used for agricultural irrigation.

$IRWQI_{SC}$ results showed spatial variations in water quality of Ghareh-chai River. Maximum value or best water quality condition was observed in station 1 located after spring (medium). The index showed a decline more than 8 units in station 2 where the river is affected by the mining in its upstream area indirectly. Water quality parameters (Table 2) showed that most of the parameters increased such as coliforms (17.63 to 40 MPN/100 mL), biological oxygen demand (2.81 to 2.94 ppm), chemical oxygen demands (51.24 to 95.31 ppm), turbidity (251.2 to 288.4 NTU), hardness (64 to 70.64 ppm), nitrate (0.89 to 1.53 ppm), and ammonium (0.27 to 0.49 ppm). Zipper et al (2016) studied on special and temporal relationship among watershed mining and water quality. The authors reported that dissolved solids, specific conductance, pH, hardness and sulfate increased significantly influenced by mining activity in long term monitoring. Specific conductance, hardness, and chemical oxygen demand were increased in rivers where contaminated via point and diffuse source of pollution of manganese mining processes (Caruso et al 2012).

Station 3 is located after a coal mine and a livestock unit. However the $IRWQI_{SC}$ did not varied much at station 3, the water quality parameters decreased in the station due to receiving the mine and livestock discharges. The water quality parameters (Table 2) confirmed it as the biological oxygen demands, fecal coliform, electrical conductivity, nitrate, ammonia, turbidity, and hardness show an increasing trend. Elevated levels of bacteria and nutrients were found in the Pittock watershed in southwestern Ontario receiving livestock waste and agricultural drainage (Thornley & Bos 1984). McDowell & Wilcock (2008) reported that water quality in agricultural catchment under different livestock (dairy, sheep, mixed or sheep-and-beef, and deer) tends to be worse than in forested catchment. They noted it has significant effect on the ecosystem of the stream including increased eutrophication associated with nutrient input, toxicity to aquatic life due to ammonia, fecal contamination, and loss of habitat or spawning area due to sedimentation. Their results showed the loads of nitrogen and phosphorous significantly more than non-agricultural catchments.

After station 3, the $IRWQI_{SC}$ decreased gradually. The river loaded the discharge of two trout farms (station 4 and 6), livestock unit (station 4 and 6), domestic (station 5) and urban waste waters (station 8). The river had the worse water quality condition in station 8 which is located in downstream and classified as fairly poor. There are many reports on aquaculture effects on environment and water quality condition (Mazaheri Kohanestani et al 2013a, 2013b; Kocer & Sevgili 2014). Karimian et al (2009) reported that agricultural effluents effects on water quality of Zohreh River (Khuzestan, Iran) and decreased the value of NSFWQI to 33 in downstream. It is reported that trout farms had significant impact on electrical conductivity, pH and biological oxygen demand in the water (Mesgaran Karimi et al 2016). Pulatsu et al (2004) assessed the impact of rainbow trout farm effluents on water quality of Karasu Stream (Turkey) and found that dissolved oxygen decreased and turbidity, nitrite, nitrate, total phosphorus, total suspended solids and ammonia increased in downstream. In our study, fecal coliform, electrical conductivity and chemical oxygen demand increased in station 4. Also, the fecal coliform, chemical oxygen demand, turbidity and hardness increased while the dissolved oxygen decreased in station 6.

Mirzaei et al (2005) who classified water quality condition of Jajrud River based on NSFWQI index reported that entering of pollution from urban areas around the river decreased water quality condition by increasing total dissolved solid and microbial counts. Results of temporal variations of water quality index ($IRWQI_{SC}$) showed that the best and worst water qualities in all stations were calculated in autumn and summer, respectively. Local smallholders start most of their agricultural activity, aquaculture and animal farming in spring and continue in summer (peak time). The dominant agricultural and aquaculture land use around the river belonged to rice paddies and trout farms. Therefore a large amount of nitrogen and phosphorous compounds were drain out the river in this period. According to results of seasonal water quality parameters (Figure 2) confirmed this claim as the maximum concentration of nitrate (1.8-5.16 ppm), ammonia (0.5-1.16 ppm), phosphate (0.89-1.16 ppm) and biological oxygen demand (3.5-3.9 ppm) were measured for summer samples. Similar results were reported by Mazaheri Kohanestani et al (2013a, 2013b). Macuiane et al (2016) observed spatial and temporal changes in water quality in Lake Malawi influenced by cage aquaculture. The authors reported there was clear seasonal change in dissolved oxygen, chlorophyll *a*, and Secchi depth at all sites. The highest chlorophyll *a* and lowest Secchi depth occurred at the farm, relative to the non-farm sites. April had the worst water quality condition.

Conclusions. Ghareh-chai River has a fairly poor water quality (36.61) receiving different type of waste waters such as agricultural, industrial, and urban/domestic discharges. The water quality at first station after the spring was classified from fairly good to average during the year showing the best condition along the river. Since there was not enough distance between different avicultures, trout farms and other pollutant resources, the river self-purification was not enough to remove all the pollution. Therefore water quality declined from upstream to downstream, as the last station after Ramian city received all the discharges and had the worst condition. The river condition was more stressful in summer due to decreasing water volume and receiving additional agricultural wastewaters. It seems urgent protective action and policy should be taken based on environmental standards to avoid future risks.

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