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Assessment of surface water resources quality in Tehran province, Iran

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ABSTRACT

Karaj and Jajrood rivers are important sources of water supply for Tehran province and special attention should be paid to water quality and its change trends in these rivers. In this study NSFWQI method as well as analytical methods was applied to determine water quality of these rivers. Water quality data sets consist of 9 parameters related to NSFWQI of three years (from April 2006 to March 2009). Parameters in 20 stations of Karaj river and 24 stations of Jajrood river have been examined monthly (except in spring and summer of 2007, as seasonally). On the basis of NSFWQI classification, water quality of two rivers classified as moderate to good quality in this period of time. Results show Karaj river has had better quality, however the WQI of dams' effluent of two rivers are similar. WQI has improved annually over time and the most and the least significant amounts of that occurred during winter and spring, respectively. Correlation analysis showed that DO and temperature have strong negative correlation; however some of other parameters have significant correlation with each other (TS and turbidity). Of the nine parameters, PO_4 has had little effect on deterioration of water quality and BOD_5 and temperature have had the most and least variations, respectively.

Keywords: Surface water; Quality assessment; NSFWQI method; ANOVA analysis; Correlation analysis; Karaj-Jajrood rivers; Iran

1. Introduction

Protecting of water bodies for all purposes such as, drinking, recreational activities, and fish and wildlife, requires regular assessing and monitoring of their quality status. The use of water quality index (WQI) is a simple and useful method to state the overall water quality conditions. A quality index is a unitless number that ascribes a quality value to an aggregate set of measured parameters. Water quality indices generally consist of sub-index scores assigned to each parameter by comparing its measurement with a parameter-specific rating curve, optionally weighted, and combined into the final index [1].

Several water quality indices have been developed to evaluate water quality. Some of the water quality indices that have been frequently employed in public domain for the purpose of water quality assessment are the National Sanitation Foundation (NSF) Water Quality Index (NSF-WQI), British Columbia Water Quality Index (BCWQI), Canadian Water Quality Index (CWQI), Oregon Water Quality index (OWQI), and the Florida Stream Water Quality Index (FWQI). Of these the NSFWQI has been

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the forerunner of many indices and its methodology continues to be adapted to this day [2].

The water quality index (WQI) was developed to give criteria for surface water classification based on the use of standard parameters for water characterization [3–17]. It is a mathematical instrument used to transform large quantities of water characterization data into a single number. Estimation of the WQI requires a normalization step where each parameter is transformed into a 0–100 scale, where 100 represents the maximum quality. The next step is to apply a weighting factor in accordance with the importance of the parameter as an indicator of water quality [8,12,13,17].

To provide a standardized method for the NSFWQI, 142 water quality scientists were surveyed about 35 parameters. In the final form, NSFWQI relied on nine parameters: DO, fecal coliform, pH, biochemical oxygen demand (BOD_5), temperature, total phosphate, nitrate, turbidity, and total solids [2,18]. In NSFWQI method, values ranges from 0–100 and waters are classified as very bad (0–5), bad (25–50), medium (50–70), good (70–90), or excellent (90–00).

Population growth and expansion of agricultural, industrial, and urban sectors are generally a threat to the integrity of water resources. The concern that fresh water will be a scarce resource in the future has forced the developing countries into the evaluation of the river water qualities in recent years [19]. It is important to consider not only quantitative but also qualitative data, since there is an emergence of new procedures and techniques that allow extracting the hidden knowledge on a great amount of data [20]. Although water quality indices are useful for water quality evaluating, statistical techniques also broadly have been used to evaluate water quality and even to create WQIs. Cluster analysis (CA), principal component analysis (PCA) and factor analysis (FA) are of conventional multivariate analyses, helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems, allows the identification of possible factors that influence water environment systems and offers a valuable tool for reliable management of water [21–23]. Dawe (2006) evaluated water quality trends in water bodies of Newfoundland and Labrador using statistical analyses [24]. Also these analyses have been used to assess violations of Water Quality Standards, surface water quality and Water pollution sources [25–29].

In this study, water quality of Karaj and Jajrood rivers has been assessed using analytical NSFWQI method to: determine water quality of Karaj and Jajrood rivers, compare water quality of Karaj and Jajrood rivers, determine correlation between parameters, and monitor water quality of these rivers comprehensively in various seasons of considered years.

2. Material and methods

2.1. Site specification

Tehran province, the capital of the Islamic Republic of Iran, is located in the south of the Alborz Mountains with an area of more than 20,000 km^2. Teheran resident's water requirements are supplied from the Karaj and Jajrood rivers and also from groundwater resources. At present about 60% of drinking water supplies is provided by the Karaj, Latyan and Lar dams near Teheran [30]. Thus Karaj and Jajrood rivers are most important sources of water supply for Tehran province.

2.1.1. Karaj river

Karaj river, one of the most important rivers of central watershed, is located in the northwest of this watershed and is one of the most important rivers of Iran. The most flow of Karaj river and its branches is applied for agricultural, municipal and industrial uses of Tehran province (Tehran, Karaj, Damavand, Varamin and Shahriar), and the remaining flow enters to Qom Salt Lake.

The Karaj surface watershed encompasses more than 5000 Km^2 with annual average precipitation of 700 mm. The river has a total length of 245 km with width of 8–15 m and depth of 1–3 m. The annual average of Karaj river flow rate at the point of Karaj dam is 450×10^6, the average and peak flow rates are 8.2 and 1450 m^3/s, respectively.

2.1.2. Jajrood river

The main branch of Jajrood river originates from the Central Alborz and Kolon Bostak mountains; this river is entered to Latyan dam and after joining to Karaj river, flows into Qom Salt Lake. The Latyan dam supply 30% of the total water demand of 11 millions people in Tehran city [31].

The watershed of this river located in the east of Damavand and northwest of Tehran. The length of this river is about 140 km and drains a catchments area of more than 3800 km^2. The annual average flow rate of that is 295×10^6 m^3 near Latyan Dam, although 134×10^6 m^3 and 555×10^6 m^3 in this place were measured as minimum and peak annual flow rates, respectively.

2.2. Data collection and analysis

In this research, some physicochemical and bacteriological data, routinely experimented each month by National Water and Wastewater Engineering Company (NWW), were used to evaluate the water quality of the Jajrood and Karaj rivers [32]. These data consist of 9 parameters, based on NSFWQI method, which were measured based on standard methods for the examination of water and wastewater: dissolved oxygen (DO) (2810-B), pH (4500-H), Biochemical oxygen demand (BOD_5) (5210-B), Temperature (To) (2550-B), Turbidity (2310-B), Total solids (TS) (2540-B), Nitrate (NO_3)(4500-NO_3-B), Phosphate (PO_4)(4500-P) and Fecal coliforms (FC) (9221-E) [33]. In this study, the quantities of total suspended solids (TSS) were missed and quantities of total dissolved solids (TDS) were just in data, but the TSS parameter was gained by multiplying the 1.3 to turbidity quantity and then the TS parameter was gained by adding TSS and TDS [34].

To monitor water quality, Tehran Water and Wastewater Company has selected 20 and 24 stations along Karaj and Jajrood rivers, respectively. Analyses and water quality data interpretations of these rivers was carried in a period of three years (from April 2006 to March 2009) were applied by Excel and SPSS softwares. Data of this period were available monthly except in spring and summer of 2007 that are seasonally. Some of samples (113 and 224 stations), due to their importance, have been carried out more than once in a month. In this study, to simplify analyses of data, stations have been numbered; Karaj as 100 and Jajrood as 200. These stations are listed in Table 1. Figs. 1 and 2 show the study areas and the sampling stations of rivers.

NSFWQI method was used to determine water quality of considered rivers. For analyzing WQI parameters, all multiple comparisons were first subjected to statistical analyses of variance (ANOVA) and significant difference between mean values of all subjects was determined using Scheffe and Sidak tests. Independent T-test also used to analyze comparison between two groups. The statistical analyses were done by SPSS software. According to water quality data, WQI of each sample was calculated by NSFWQI software, otherwise 536 WQI for Karaj river and 479 WQI for Jajrood river were obtained [35].

The weight factor for NSFWQI was developed using an equation of Brown et al. (1970) [36].

$$\text{NSFWQI} = \sum_{i=1}^{n} W_i I_i \quad (1)$$

where I_i = the quality of the ith parameter (a number between 0 and 100 read from the appropriate sub-index graph)

And W_i = the weight factor of the ith parameter

To investigate correlation between parameters correlation test is used, correlation coefficient state the

Table 1
Sampling stations of Karaj (100) and Jajrood (200) rivers

No.	Station	No.	Station	No.	Station	No.	Station
101	Before Hotel Gachsar	112	Hotel varyan	203	After Zaygan	214	Outlet of Hajiabad
102	After Hotel Gachsar	113	Outlet of Tanzimi Dam	204	After Rute conjunction	215	After Roodak
103	Deh e Emamzade Hasan	114	Pol e Kamp	205	Shemshak	216	Outlet of Zarband
104	Restaurant loshato	115	Abshar	206	After Darbansar	217	After Pol e Lashkarak
105	Outlet of Shahrestanak	116	Baq kanevadegi ziba	207	Before Meygoon	218	Latyan inlet-kandrood
106	After Pol e Shahrestanak	117	Above Malek Qotbi	208	Outlet of Meygoon	219	Latyan inlet-afje
107	Hotel pamchal	118	Restaurant ladan	209	Doab	220	Befor Rasnan
108	Goosht e Mahan	119	Bilaqan inlet	210	Outlet of Ahar	221	Outlet of Rasnan
109	Deh asara	120	Outlet of Bilaqan	211	Eigol	222	Outlet of Kalan
110	Before Pol e Khab	201	After Garmabdar	212	After Eigol	223	Latyan Inlet-Dar e Lorak
111	Inlet to Karaj Dam	202	Mixture of Garabdar and Abenik	213	After Oushan	224	Outlet of Latyan

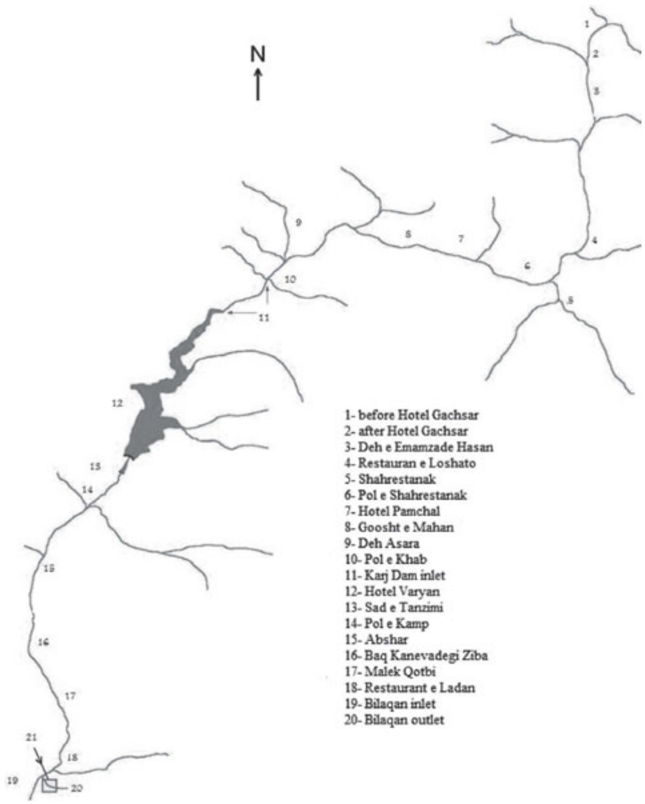

Fig. 1. Karaj river plan and monitoring stations location.

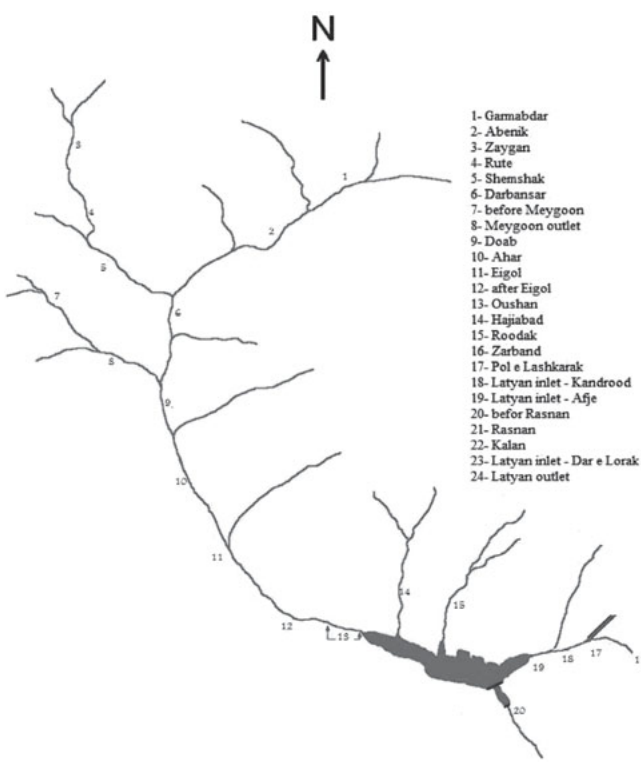

Fig. 2. Jajrood river plan and monitoring stations location.

importance of correlation, the possible values of the coefficient range from –1 to +1. If two variables are independent the coefficient would be zero. Values approaching +1 or –1 indicate a strong correspondence of two variables [37].

3. Results and discussion

3.1. Water quality of Karaj and Jajrood rivers

Tables 2 and 3 shows averages and standard deviations of quality parameters considered in NSFWQI and sub-index and weight factor of NSFWQI for Karaj and Jajrood rivers, respectively. The average values of considered parameters of NSFWQI method along with summary statistics results of Karaj and Jajrood rivers during 2006–2009 has been presented in Tables 4 and 5, Skewness shows abnormality of data. Box plots were created with Minitab software to permit the comparison of WQI in different sites on that duration (Fig. 3). Mean, median, standard deviation (SD), confidence level and outliers of WQI for each station have been shown in the Box plot. The results of station 106 (SD = 7) and station 222 (SD = 6.1) along Karaj and Jajrood rivers had the most significant variance during the studied period. Along the Karaj and Jajrood rivers, the WQI was varied between 57–89 and 57–86, respectively; thus in accordance to NSF classification, two rivers has good and mostly intermediate quality.

Independent t-test results in Table 6 show that water quality of Karaj river (average WQI = 76) is better than that of Jajrood river (average WQI = 71), although this test did not show any difference in the water quality of intake points of two rivers; station 224 of Jajrood river and stations 113 and 120 of Karaj river (P_{value}<0.05).

3.2. Water quality changes of two rivers

To evaluate water quality along Karaj river, 6 stations (106, 107, 108, 109, 113, 114, 115, 116, 117, 119 and 120) was selected. The One-way ANOVA analysis showed difference along various stations duo to station 113 (P_{value}< 0.001), and WQI of other stations did not have significant difference with each other. To survey this trend along Jajrood river 8 stations was undertaken. WQI along this river varied (P_{value}< 0.001) and average of WQI along these stations was at: 224>202>203>216>215>217>213>214, although station 224 played the main role in this difference, similar to station 113 in Karaj river. Jajrood river has four inflow sites (Fig. 2); the water quality of total entrance branches to Latyan dam including stations 217, 218, 219 and 223 and output point of this dam, 224, also investigated separately. Among of these five stations, water quality of station 224 was different and the

Table 2
Average and standard deviation of quality parameters of Karaj and Jajrood rivers

Station No.	T (°C)	FC (MPN/100 ml)	pH	Turb. (NTU)	TS (mg/l-$CaCO_3$)	NO_3 (mg/l-N)	BOD_5 (mg/l)	PO_4 (mg/l)	DO (mg/l)
101	6.92±3.67	1346.90±4761.26	8.34±0.11	9.88±17.57	200.88±22.74	2.73±0.88	1.75±0.97	0.029±0.01	8.49±1.03
102	7.19±3.66	1347.36±2567.61	8.32±0.11	12.23±20.24	257.55±50.93	2.73±0.97	1.62±0.50	0.031±0.021	8.69±1.14
103	7.48±3.87	826.99±2014.77	8.15±0.06	29.07±85.56	265.05±55.16	2.78±0.97	1.46±0.59	0.03±0.02	8.64±1.24
104	7.44±3.83	1121.09±2117.04	8.24±0.06	32.86±86.86	270.15±55.38	2.81±0.96	1.58±0.75	0.04±0.04	8.60±1.08
105	8.17±4.49	361.98±617.56	8.21±0.12	34.97±116.63	202.20±25.19	3.44±0.95	1.75±0.70	0.04±0.02	8.44±1.21
106	7.91±3.99	279.16±550.67	8.28±0.12	33.61±73.86	247.32±40.84	2.90±0.56	1.56±0.56	0.03±0.02	8.77±1.38
107	7.93±3.97	281.22±459.98	8.31±0.14	39.63±88.63	251.12±41.35	2.86±0.55	1.51±07	0.03±0.02	8.80±1.22
108	8.23±3.98	333.08±758.23	8.34±0.12	41.91±94.21	248.82±39.61	2.91±0.57	1.51±0.61	0.03±0.02	8.87±1.31
109	8.50±4.18	905.12±2510.29	8.37±0.12	48.20±108.93	246.35±37.45	2.96±0.58	1.50±0.61	0.03±0.02	8.88±1.25
110	9.00±4.76	1712.17±4665.69	8.37±0.11	73.64±164.75	232.04±41.03	3.04±0.74	1.84±0.84	0.03±0.02	8.72±0.92
111	8.91±3.43	2574.05±6239.15	8.33±0.18	59.97±147.20	223.33±39.16	3.27±01.19	2.01±0.85	0.04±0.03	8.81±1.22
112	12.50±4.53	9.81±13.99	8.36±0.17	3.68±2.28	190.86±24.82	2.89±01.20	1.50±0.74	0.03±0.02	8.25±1.01
113	10.71±2.73	1174.16±6694.38	8.24±0.12	4.73±2.98	196.72±22.62	3.64±0.80	1.85±0.70	0.03±0.02	8.55±0.94
114	9.91±2.72	436.09±715.84	8.30±0.10	5.01±3.19	203.37±20.64	3.46±1.14	1.87±0.67	0.03±0.01	9.05±0.92
115	9.90±3.04	347.68±404.17	8.37±0.13	6.07±5.33	201.02±21.43	3.21±0.94	1.65±0.59	0.03±0.03	8.95±0.93
116	9.48±3.22	4899.60±18587.41	8.33±0.10	6.02±3.79	202.63±19.81	3.41±0.99	2.03±0.79	0.02±0.01	8.72±0.82
117	9.52±3.17	2537.08±10740.70	8.32±0.07	6.07±4.37	204.62±19.45	3.41±0.99	1.82±0.75	0.02±0.01	8.84±0.85
118	9.68±3.07	982.13±2729.07	8.31±0.089	6.83±5.49	214.76±35.68	3.35±0.97	1.71±0.50	0.02±0.01	8.74±0.92
119	9.92±3.13	1531.88±3909.05	8.32±0.080	7.18±6.24	208.53±24.33	3.45±1.07	1.54±0.41	0.02±0.01	8.73±0.85
120	10.04±3.13	531.38±1030.90	8.27±0.10	6.81±6.39	231.42±57.89	3.27±0.99	1.57±0.50	0.02±0.01	8.66±01.08
201	6.85±4.37	4263.38±14944.46	8.19±0.22	7.63±9.08	194.09±27.59	3.68±.73	1.53±0.70	0.03±0.03	8.31±1.14
202	6.54±3.95	2061.43±5093.88	8.36±0.10	10.39±13.11	170.92±24.30	4.12±1.85	1.44±0.50	0.03±0.02	8.74±1.08
203	7.13±4.05	947.33±1733.99	8.32±0.17	11.69±13.82	183.91±20.54	4.35±2.28	1.463±0.52	0.03±0.01	8.75±1.11
204	10.40±2.07	94.20±88.38	8.31±0.07	19.82±13.69	213.06±57.60	5.47±1.011	1.420±0.34	0.04±0.02	7.76±0.82
205	7.55±4.65	21271.43±15333.70	8.39±0.17	128.23±259.96	291.19±82.79	3.48±0.99	3.136±0.07	0.06±0.02	8.10±0.90
206	7.36±4.10	13439.24±43329.41	8.42±0.20	103.45±419.14	220.31±42.53	3.74±1.37	1.832±0.71	0.04±.01	8.52±1.04
207	8.09±4.26	2016.26±3872.20	8.46±0.16	97.20±357.30	235.82±33.98	4.50±2.95	2.005±0.79	0.04±0.02	8.70±1.17
208	8.45±4.55	9806.11±18195.56	8.41±0.21	22.87±31.66	288.92±47.99	4.79±2.88	2.940±1.17	0.07±0.04	8.53±1.24
209	7.96±4.52	2508.20±4691.80	8.44±0.19	95.51±296.28	218.57±27.41	4.53±0.93	1.800±0.61	0.04±0.02	8.94±1.19
210	8.04±3.94	3321.27±6015.17	8.30±0.19	8.77±17.45	250.61±64.99	3.95±0.65	1.817±0.71	0.04±0.02	8.58±1.13
211	8.50±3.82	2862.42±4660.56	8.36±0.17	9.45±12.99	203.94±59.96	4.15±0.84	1.917±0.51	0.05±0.01	8.19±1.06
212	7.64±4.43	879.18±1031.80	8.33±0.15	3.72±4.38	242.38±49.18	4.24±0.96	1.455±0.31	0.04±0.02	8.94±1.26
213	8.48±3.82	3649.21±6245.23	8.37±0.19	75.34±195.49	226.90±37.29	4.91±0.67	1.791±0.55	0.05±0.02	8.59±1.13
214	8.65±3.84	1406.22±2037.75	8.44±0.20	160.20±371.12	223.43±35.55	4.83±0.77	1.639±0.55	0.05±0.03	8.73±1.12
215	9.09±4.05	1077.53±2019.51	8.41±0.14	97.45±260.07	219.60±32.87	5.13±0.85	1.838±0.51	0.04±0.02	8.81±1.09
216	8.90±4.35	2374.94±5210.36	8.40±0.18	35.12±68.33	224.00±32.55	5.26±0.85	1.789±0.56	0.04±0.03	9.05±1.19
217	9.10±4.58	4043.33±12563.88	8.44±0.11	39.91±77.08	230.02±50.40	5.04±0.89	2.068±0.90	0.04±0.02	9.08±1.20
218	7.53±4.03	632.62±921.89	8.40±0.05	50.47±51.83	296.22±55.11	8.30±2.21	1.800±01.10	0.04±0.02	9.30±1.13
219	9.67±5.15	661.56±1833.45	8.31±0.10	5.16±6.17	368.01±82.91	12.88±2.13	1.729±0.86	0.04±0.02	8.70±1.14
220	8.33±5.00	867.00±1236.23	8.23±0.23	6.00±5.43	431.38±78.64	6.46±1.83	1.322±0.41	0.03±0.01	8.71±1.52
221	9.20±5.66	11388.05±44542.64	8.27±0.14	7.25±8.66	467.62±116.19	5.98±1.23	1.620±0.70	0.05±0.10	8.60±1.35
222	11.70±4.13	270.58±480.74	8.32±0.08	4.37±4.86	258.63±136.51	3.59±1.33	1.990±0.83	0.03±0.02	8.25±1.21
223	9.95±5.97	1423.10±4429.33	8.34±0.09	13.76±14.33	342.73±125.82	5.08±1.87	1.515±0.57	0.03±0.02	8.65±1.36
224	12.93±5.38	111.37±327.69	8.23±0.14	9.49±13.64	209.30±32.77	4.81±1.27	1.525±0.75	0.03±0.01	7.77±1.14

Table 3
Sub-index, weight factor and WQI for Karaj and Jajrood rivers

Quality parameters	T		FC		pH		Turb		TS		NO_3		BOD_5		PO_4		DO		Final WQI
Station No.	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	Sub-index	WQI	
101	8.90	89.00	7.21	45.08	7.87	71.56	6.26	78.24	4.66	66.64	7.62	76.16	9.43	85.76	9.86	98.60	12.61	74.16	74.43
102	8.70	87.00	5.85	36.56	7.92	72.04	6.40	79.96	4.38	62.64	8.95	89.52	9.55	86.80	9.88	98.76	12.78	75.16	74.41
103	8.50	85.00	7.09	44.32	8.64	78.56	6.20	77.56	4.21	60.12	8.80	88.04	9.75	88.64	9.86	98.60	12.87	75.72	75.93
104	8.50	85.00	6.82	42.60	8.30	75.44	5.96	74.52	4.12	58.80	8.83	88.28	9.51	86.44	9.82	98.24	12.82	75.44	74.68
105	8.50	85.00	7.77	48.57	8.39	76.26	6.35	79.43	4.76	68.00	8.20	82.00	8.92	84.77	9.82	98.17	12.80	75.30	75.51
106	8.50	85.00	8.30	51.86	8.13	73.91	5.43	67.91	4.20	60.05	8.59	85.91	9.65	87.68	9.42	98.67	13.01	76.55	75.23
107	8.50	85.00	7.72	48.27	7.98	72.50	5.74	71.73	4.14	59.14	8.81	88.09	9.74	88.50	9.85	98.50	13.32	78.36	75.79
108	8.50	85.00	8.12	50.73	7.87	71.50	5.80	72.45	4.17	59.55	8.74	87.36	9.70	88.14	9.85	98.45	13.59	79.95	76.32
109	8.50	85.00	8.04	50.23	7.79	70.82	5.70	71.23	4.12	58.82	8.69	86.86	9.70	88.14	9.86	98.59	13.75	80.91	76.14
110	8.50	85.00	6.92	43.23	7.75	70.45	5.72	71.50	4.13	58.95	8.53	85.27	9.17	83.36	9.85	98.45	13.72	80.68	74.27
111	8.50	85.00	7.19	44.91	7.82	71.09	6.02	75.30	4.27	61.04	8.49	84.87	9.04	82.22	9.82	98.22	13.70	80.61	74.86
112	8.50	85.00	13.19	82.45	7.76	70.55	7.11	88.86	5.14	73.36	8.77	87.73	9.63	87.50	9.86	98.64	14.04	82.59	84.00
113	8.50	85.00	9.23	57.66	8.28	75.30	6.94	86.77	5.06	72.29	7.91	79.05	9.12	82.93	9.85	98.53	14.05	82.64	78.94
114	8.50	85.00	7.36	46.00	8.08	73.43	6.91	86.35	5.00	71.39	8.26	82.61	9.09	82.61	9.85	98.52	14.44	84.96	77.49
115	8.50	85.00	6.38	39.86	7.76	70.55	6.63	82.82	4.55	65.05	7.77	77.68	9.22	83.82	9.70	97.05	14.00	82.36	74.51
116	8.50	85.00	6.32	39.52	7.94	72.20	6.41	80.08	4.57	68.04	8.03	80.32	9.21	83.72	9.84	98.40	13.10	77.04	73.92
117	8.50	85.00	6.30	39.36	7.97	72.44	6.55	81.84	4.48	64.00	7.87	78.68	9.46	85.96	9.86	98.60	13.46	79.16	74.43
118	8.50	85.00	6.20	40.33	8.03	73.00	6.79	84.84	4.63	66.08	7.90	79.04	9.21	83.72	9.86	98.64	13.61	80.04	74.72
119	8.50	85.00	6.07	37.92	7.97	72.48	6.62	82.76	4.71	70.13	8.26	82.64	9.61	87.40	9.89	98.92	14.32	84.24	75.96
120	8.50	85.00	8.16	51.00	8.15	74.08	6.68	83.46	4.71	67.35	8.39	83.92	9.56	86.88	9.88	98.81	14.08	82.85	78.11
201	8.50	85.00	7.15	44.69	8.42	76.54	6.63	82.85	5.06	72.23	7.85	78.54	9.62	87.46	9.85	98.54	11.95	70.31	75.03
202	8.50	85.00	5.98	37.38	7.83	71.21	6.34	79.21	5.01	74.70	7.75	77.50	9.75	88.63	9.86	98.63	12.73	74.88	73.75
203	8.50	85.00	5.89	36.79	7.96	72.38	6.19	77.33	4.87	72.65	7.57	75.71	9.73	88.42	9.85	98.50	13.00	76.46	73.55
204	8.50	85.00	8.16	51.00	8.03	73.00	5.26	65.80	4.73	67.60	6.32	63.20	9.88	89.80	9.86	98.60	12.41	73.00	73.15
205	8.50	85.00	2.59	16.18	7.71	70.09	3.30	41.27	3.35	47.91	7.95	79.55	7.58	68.91	9.74	97.36	11.84	69.64	62.56
206	8.50	85.00	4.33	27.05	7.59	68.95	5.59	69.82	4.58	65.41	7.83	78.32	9.15	83.14	9.82	98.18	12.61	74.18	69.98
207	8.50	85.00	5.22	32.64	7.43	67.55	5.11	63.86	4.33	61.86	7.63	76.32	8.89	80.77	9.81	98.09	13.28	78.14	70.20
208	8.50	85.00	2.58	16.15	7.60	69.10	5.39	67.35	4.00	57.10	7.32	73.20	7.72	70.15	9.69	96.85	13.10	77.05	65.89
209	8.50	85.00	4.64	29.00	7.50	68.17	5.23	65.39	4.38	62.52	6.96	69.57	9.14	83.13	9.83	98.30	13.67	80.43	69.85
210	8.50	85.00	4.68	29.26	8.07	73.35	6.74	84.30	4.50	64.35	7.47	74.65	9.16	83.26	9.82	98.22	12.99	76.39	71.93
211	8.50	85.00	3.93	24.58	7.81	71.00	6.57	82.17	4.93	70.42	7.38	73.75	8.89	80.83	9.79	97.92	12.44	73.17	70.24
212	8.50	85.00	5.43	33.91	7.93	72.09	7.15	89.36	4.65	66.36	7.29	72.91	9.83	89.36	9.80	98.00	13.51	79.45	74.08
213	8.50	85.00	4.42	27.65	7.74	70.35	5.34	66.70	4.19	59.87	6.58	65.78	9.14	83.09	9.78	97.78	13.22	77.78	68.91
214	8.50	85.00	4.78	29.87	7.50	68.17	4.46	55.70	3.96	56.52	6.66	66.61	9.41	85.52	9.77	97.74	13.59	79.96	68.63
215	8.50	85.00	5.90	36.90	7.60	69.10	4.99	62.38	4.17	59.52	6.49	64.86	9.10	82.71	9.81	98.14	13.92	81.90	70.48
216	8.50	85.00	5.34	33.37	7.63	69.37	5.26	65.79	4.41	63.00	6.42	64.16	9.22	83.79	9.85	98.47	14.23	83.68	70.85
217	8.50	85.00	4.57	28.58	7.51	68.26	5.13	64.11	4.31	61.58	6.55	65.53	8.77	79.68	9.83	98.32	14.32	84.26	69.49
218	8.50	85.00	6.22	38.86	7.65	69.57	3.90	48.79	3.55	50.71	5.55	55.50	9.33	84.86	9.82	98.21	14.15	83.21	68.68
219	8.50	85.00	6.89	43.06	8.00	72.71	6.98	87.29	3.48	49.65	4.66	46.65	9.30	84.59	9.83	98.29	13.88	81.65	71.52
220	8.50	85.00	6.26	39.11	8.27	75.22	6.79	84.89	2.85	40.78	6.02	60.22	9.97	90.67	9.87	98.67	13.18	77.56	71.72
221	8.50	85.00	5.46	34.15	8.16	74.15	6.71	83.90	2.53	36.10	6.16	61.55	9.45	85.90	9.67	96.70	13.45	79.10	70.08
222	8.50	85.00	8.40	52.50	7.95	72.30	7.04	88.00	4.42	63.10	7.95	79.50	8.77	79.70	9.87	98.70	13.82	81.30	76.72
223	8.50	85.00	6.55	40.95	7.90	71.81	6.00	74.95	3.54	50.57	6.86	68.57	9.18	87.65	9.86	98.62	13.83	81.38	72.22
224	8.50	85.00	10.97	68.57	8.31	75.52	6.41	80.07	4.51	69.42	6.91	69.13	9.63	87.54	9.88	98.80	13.18	77.52	78.29

Table 4
Descriptive statistics for the Karaj river water quality data

	N	T	FC	EC	pH	Turb.	TS	NO_3	BOD_5	PO_4	DO
Max	536	23	92000	605	8.84	562	892.93	15.3	4.4	0.5	11.5
Mean	536	9.1	1215	357.45	8.30	22.54	259.69	3.32	1.67	0.04	8.64
Min	536	0	1	231	7.84	0.6	137.46	0.7	0.5	0	5.6
Mode	536	11	23	300	8.31	3	213.67	2.29	1	0.02	8.4
Median	536	10	110	344.5	8.3	3.6	233.76	3.2	1.6	0.03	8.6
Std. Deviation	536	3.78	5936	71.18	0.13	72.06	100.49	1.33	0.67	0.03	1.10
Kurtosis	536	0.14	135	0.23	1.42	30.18	15.85	20.96	0.83	88.93	–0.33
Skewness	536	–0.22	10.55	0.81	–0.02	5.35	3.55	3.28	0.86	6.89	0.20

Table 5
Descriptive statistics for the Jajrood river water quality data

	N	T	FC	EC	pH	Turb.	TS	NO_3	BOD_5	PO_4	DO
Max	477	24	160000	1036	8.95	1979	2778.4	16.3	6.6	0.5	11.3
Mean	477	9.05	3094	404.48	8.35	43.23	305.37	5.06	1.78	0.04	8.55
Min	477	0	1	195	7.6	0.2	149.89	1.7	0.4	0.01	5.4
Mode	477	8	350	320	8.4	3	279.57	3.7	1	0.03	8.4
Median	477	9	240	366	8.35	7.8	250.39	4.59	1.7	0.04	8.6
Std. Deviation	477	4.85	12684	142.96	0.18	180.4	240.24	2.31	0.80	0.03	1.21
Kurtosis	477	–0.50	109.05	2.65	1.30	63.56	51.12	6.77	3.51	68.83	–0.44
Skewness	477	0.25	9.59	1.57	0.01	7.63	6.47	2.33	1.30	5.79	0.04

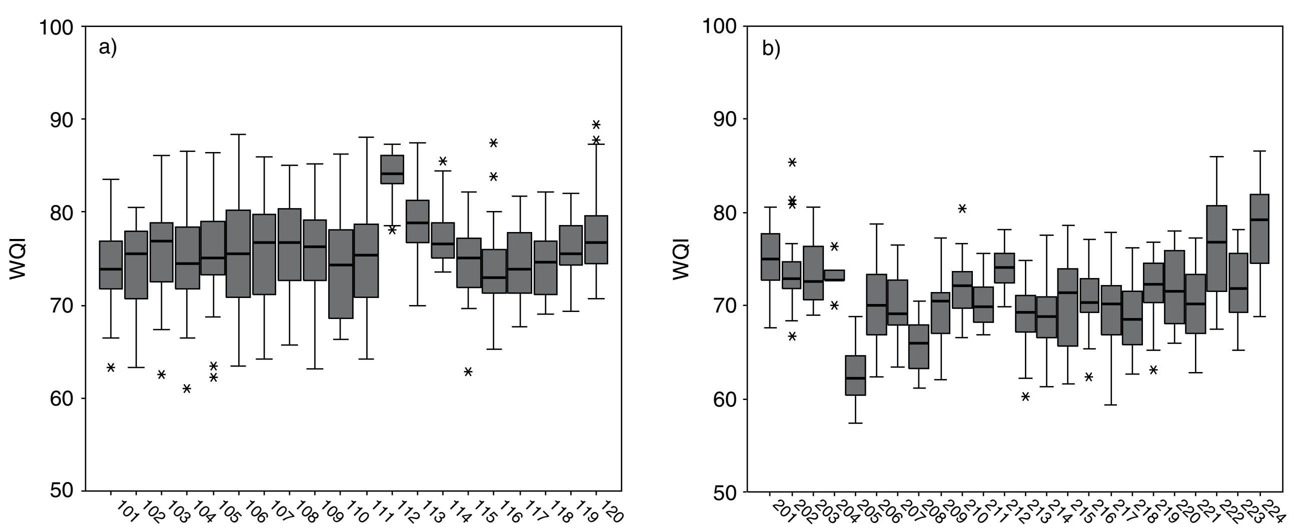

Fig. 3. Box plot of WQI of two rivers from 2006 to 2008: (a) Karaj river, (b) Jajrood river.

best; differences between other stations are insignificant at 95% confidence interval (P_{value}<0.05).

Moreover, WQI trends along stations of two rivers indicate improvement in the water quality in stations 113 and 224 due to transformation of river into dam, which acts as sedimentation or may be degradation pond. Also Fig. 4 demonstrates average of WQI along total stations during two study periods (2006 and 2008). WQI of two rivers had varied during three years. They have had a least quality during 2006.

Fig. 5 demonstrates time-series chart of annual averages of changes trends of WQI parameters in last 10 years of Latyan and Bilaghan effluents. The DO and Phosphate parameters hadn’t considerable changes to show.

Table 6
Independent samples test for comparing WQI of Karaj and Jajrood rivers

	River	N	Mean	Std. deviation	Std. error mean	Levene's test for equality of variances		t-test for equality of means						
WQI	400	536	76.126	5.3480	.2310	F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
	401	477	71.763	5.3933	.2469								Lower	Upper
WQI	Equal variances assumed					.003	.954	12.911	1011	.000	4.363	.3380	3.7002	5.0267
	Equal variances not assumed							12.904	995.39	.000	4.363	.3381	3.6999	5.0270

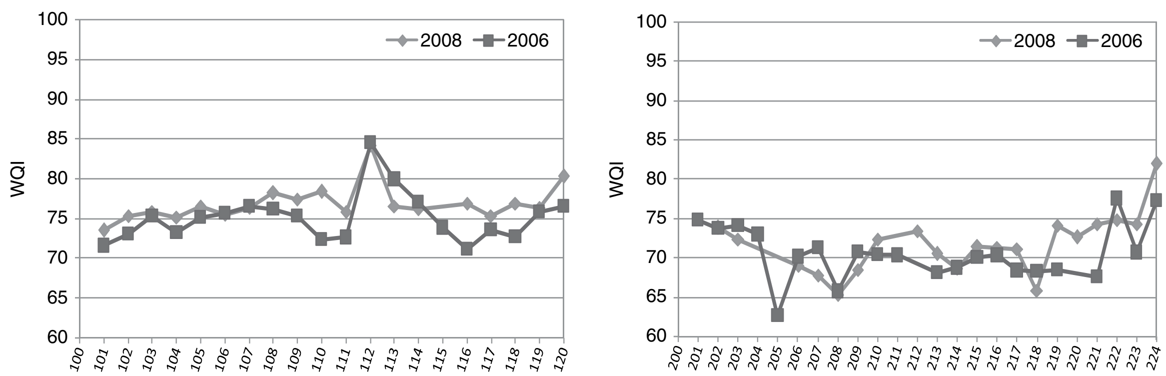

Fig. 4. WQI changes along Karaj and Jajrood rivers stations during two years.

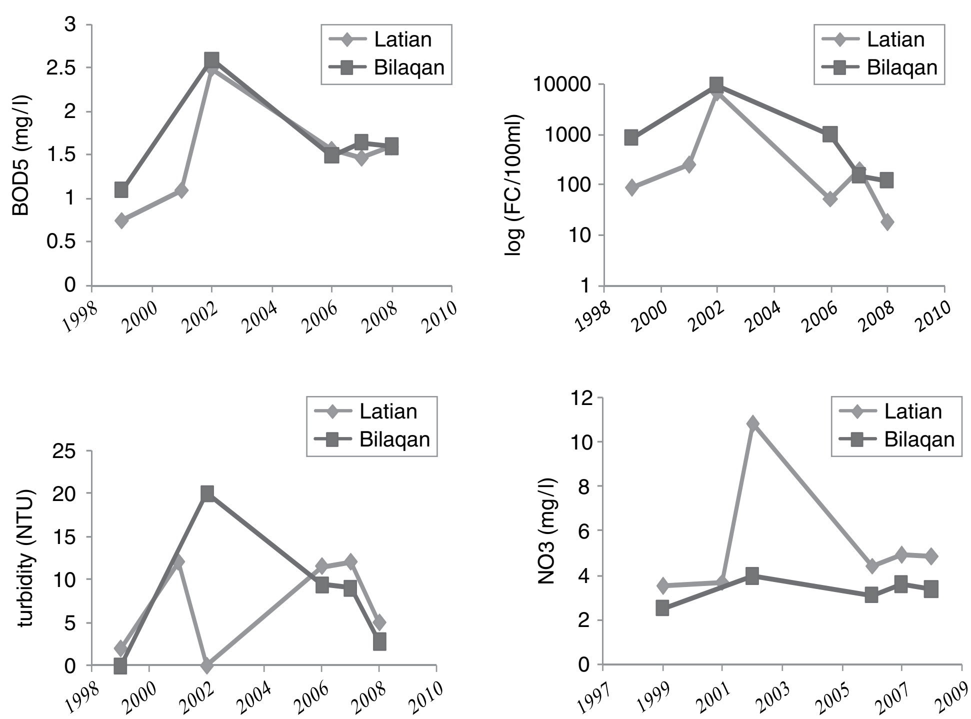

Fig. 5. Time Series plot of some parameters in about recent 10 years.

Annually water quality changes may be resulting of changes in climate and precipitation or pollutants loadings, Precipitation can dilute chemical pollutants. The effect of season on the water quality of Karaj and Jajrood rivers also was detected. Seasonal trends of WQI and other parameters show that the best quality of water occurs in winter and the worst quality occurs in spring, in the view of DO and WQI. Two rivers have experienced maximum turbidity and PO_4 in spring, although minimum of FC and water temperature has occurred in winter. In springs, due to high rainfall rates and flowing runoff over the land surface, the water can cause soil and other materials to erode, which may content minerals like phosphate, which results in increased turbidity and also PO_4. In winter, due to low weather temperature and therefore river temperature, the accumulation of FC would be decreased, because of low tolerant of FC against coldness [38]. Precipitation and flow rate of most rivers were maximized in winter and contrary water recreational activities and other usages of water were minimized in this season. These subjects and changes in water temperature may be attributed to seasonally changes of water quality. Although BOD_5 had not changed during varies seasons. It seems that organic contaminants with different sources such as domestic, agricultural, industrial and natural which have entered to the banks of Karaj and Jajrood rivers cause BOD_5 to be more stable during various seasons.

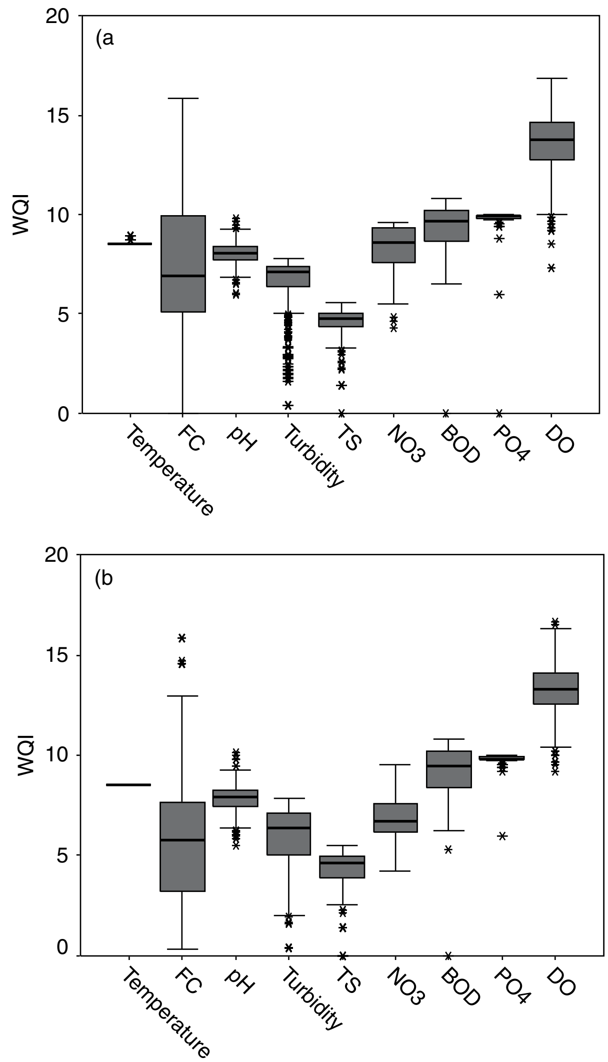

Fig. 6. Factors vs. WQI weighting factor: (a) Karaj river, (b) Jajrood river.

3.3. Quality parameters effects on WQI

In accordance to NSF classification that the best quantity for WQI has been 100, parameters related to WQI have been shown in Fig. 6. As can be seen, the Phosphate parameter had less effect on WQI changes, however FC and Temperature had the most and the least changes in studied rivers, respectively. The importance of the phosphate in water quality studies is its role in algeal blooming in water resources. However, the weighting factor of this parameter is 0.1 which caused to be less considerable than for instance DO (0.17) or FC (0.16). The concentration of the phosphate in the Karaj and Jajrood rivers were less than 1 mg/l (inhibitor concentration) which could not support algeal blooming.

3.4. Correlation coefficient analysis

In this study, Bi-variant correlation was used to delineate relationships between WQI parameters; the correlation matrixes of water quality parameters of Karaj river in Table 7 and of Jajrood river in Table 8 have been abstracted. There has been rarely strong correlation between parameters, except to DO with temperature and TS with turbidity. Although most of the parameters have significant association with others, DO and temperature have maximum correlation with other parameters, in Karaj river. Moreover, TS correlate with turbidity which is due to the relation between them in occurrence in water resources. However, the correlation between DO, BOD and FC has not been considerable. As noticed above, external sources may cause Karaj and Jajrood rivers to be contaminated and due to high amounts of water intake from these two rivers, the self-purification capacity of rivers has been decreased justifiably. The temperature of water determines how much oxygen can be held in solution. Everything else being equal, cold water contains more oxygen than warm water due to more oxygen dissolved capacity of water. As temperature increases, dissolved oxygen decreases [38].

Table 7
Correlation coefficient and equation of water quality parameters for Karaj river

	T		DO		FC		pH		TS		NO_3		BOD_5		Turb.		PO_4	
	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.
T	1																	
DO	–.630**	$Y=-2.201X+28.22$ (r^2=.396)	1															
FC	.169**	$Y=0.0001X+9.03$ (r^2=.027)	–.113*	$Y=0.00002X+8.68$ (r^2=.013)	1													
PH	–.104*	$Y=-2.38X+28.92$ (r^2=.007)	.237**	$Y=1.93X-7.34$ (r^2=.053)	–.019	$Y=-749.79X+7435.16$ (r^2=.001)	1											
TS	–.224**	$Y=-0.008X+11.32$ (r^2=.048)	.082	$Y=0.001X+8.39$ (r^2=.008)	–.045	$Y=-4.35X+2265.16$ (r^2=.001)	–.020	$Y=-0.00001X+8.31$ (r^2=.001)	1									
NO_3	–.090*	$Y=-3.11X+10.97$ (r^2=.012)	.134**	$Y=0.18+8.26$ (r^2=.02)	.086	$Y=379.27X-58.06$ (r^2=.005)	–.013	$Y=-0.001X+8.31$ (r^2=.001)	125**	$Y=9.65X+226.44$ (r^2=.016)	1							
BOD_5	.104*	$Y=0.581X+8.2$ (r^2=.01)	.017	$Y=0.027X+8.605$ (r^2=.002)	.017	$Y=146.17X+98.07$ (r^2=.001)	–.059	$Y=-0.013X+8.32$ (r^2=.004)	–.087*	$Y=-11.28X+277.93$ (r^2=.006)	.131**	$Y=0.267X+2.86$ (r^2=.02)	1					
Turb.	–.040	$Y=-0.002X+9.21$ (r^2=.002)	–.053	$Y=-0.001X+8.66$ (r^2=.002)	.060	$Y=17.34X+1057.76$ (r^2=.003)	–.090*	$Y=0.0001X+8.31$ (r^2=.006)	.835**	$Y=1.162X+233.05$ (r^2=.69)	.051	$Y=0.001X+3.22$ (r^2=.002)	–.028	$Y=0.0003X+1.67$ (r^2=.001)	1			
PO_4	.101*	$Y=11.83X+8.75$ (r^2=.01)	–.185**	$Y=-6.29X+8.87$ (r^2=.03)	.054	$Y=10297.21X+872.57$ (r^2=.003)	–.034	$Y=-0.0106X+8.31$ (r^2=.001)	.384**	$Y=1214.89X+214.15$ (r^2=.15)	.066	$Y=2.57X+3.21$ (r^2=.004)	–.013	$Y=-0.096X+1.67$ (r^2=.001)	.380**	$Y=849.76X-8.86$ (r^2=.14)	1	
WQI	–.149**	$Y=-0.118X+17.03$ (r^2=.02)	.435**	$Y=0.098X+2.09$ (r^2=.18)	–.302**	$Y=-394.18X+27811.55$ (r^2=.09)	.060	$Y=0.001X+8.22$ (r^2=.002)	–.378**	$Y=-6.62X+703.05$ (r^2=.1)	–.218**	$Y=-0.063X+7.59$ (r^2=.05)	–.024	$Y=-0.005X+2.03$ (r^2=.001)	–.359**	$Y=-5.16X+368.59$ (r^2=.12)	–.335**	$Y=-0.002X+0.184$ (r^2=.11)

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 8
Correlation coefficient and equation of water quality parameters for Jajrood river

	T		DO		FC		pH		TS		NO_3		BOD_5		Turb.		PO_4	
	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.	Coef.	Eq.
T	1																	
DO	−.826**	Y= −3.32X+ 37.47 (r^2=.68)	1															
FC	.097*	Y= 0.00003X+ 8.99 (r^2=.009)	−.158**	Y= 0.0001X+ 8.59 (r^2=.025)	1													
PH	−.315**	Y= −8.66X+ 81.36 (r^2=.1)	.368**	Y= 2.51X− 12.37 (r^2=.136)	−.047	Y= −314.93X+ 29394.66 (r^2=.002)	1											
TS	.023	Y= 0.0004X+ 8.91 (r^2=.001)	.008	Y= 0.0004X+ 8.54 (r^2=.001)	.143**	Y= 19.87X− 2281.94 (r^2=.02)	−.085	Y= −0.0006X+ 8.37 (r^2=.007)	1									
NO_3	−.047	Y= −0.099X+ 9.55 (r^2=.002)	.146**	Y= 0.076X+ 8.16 (r^2=.021)	−.036	Y= 4037.74X− 191.31 (r^2=.001)	−.114*	Y= −0.009X+ 8.39 (r^2=.013)	.163**	Y= 16.92X+ 219.78 (r^2=.026)	1							
BOD_5	.063	Y= 0.39X+ 8.347 (r^2=.004)	−.005	Y= −0.008X+ 8.57 (r^2=.001)	.182**	Y= 2854.07X− 1955.97 (r^2=.03)	.061	Y= 0.014X+ 8.33 (r^2=.004)	.006	Y= 2.03X+ 302.05 (r^2=.001)	−.077	Y= −0,22X+ 5.47 (r^2=.006)	1					
Turb.	.020	Y= 0.001X+ 9.03 (r^2=.0001)	−.014	Y= 0.0009 X+ 8.56 (r^2=.001)	.019	Y= 12.15X+ 2923.77 (r^2=.001)	−.052	Y= −0.0005X+ 8.35 (r^2=.003)	.928**	Y= 1.23X+ 252.17 (r^2=.87)	.006	Y= 0.0007X+ 5.05 (r^2=.001)	−.014	Y= 0.0006X+ 1.78 (r^2=.005)	1			
PO_4	.094*	Y= 13.53X+ 8.46 (r^2=.009)	−.143**	Y= −5.08X+ 8.77 (r^2=.02)	.045	Y= 16898.9X+ 2364.42 (r^2=.002)	−.103*	Y= −0.53X+ 8.37 (r^2=.01)	.201**	Y= 1428.22X+ 243.63 (r^2=.041)	−.020	Y= −1.34X+ 5.21 (r^2=.001)	.169**	Y= 3.91X+ 1.6 (r^2=.028)	.160**	Y= 846.81X+ 6.08 (r^2=.025)	1	
WQI	.081	Y= 0.083X+ 3.79 (r^2=.006)	.067	Y= 0.017X+ 7.48 (r^2=.004)	−.304**	Y= −831.53 X+ 55714.39 (r^2=.092)	−.096*	Y= −0.004X+ 8.59 (r^2=.011)	−.354**	Y= −15.93X+ 1308.5 (r^2=.096)	−.165**	Y= −0.082X+ 10.25 (r^2=.028)	−.268**	Y= −0.045X+ 4.36 (r^2=.071)	−.220**	Y= −8.44X+ 574.77 (r^2=.048)	−.366**	Y= −0.003X+ 0.21 (r^2=.132)

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

In spite of the fact that when two variables are independent, value of coefficient approach is zero, if two variables are also functionally related, the computed of the correlation coefficient (r) is not likely to approach ±1. A scatter plot of the data reveal whether a low value of r result from large random scatter in the data, or from a nonlinear relation between the variables [37]. The scatter plot of data (Fig. 6) shows no nonlinear correlations between WQI parameters (FC parameter has been in logarithmic scale) and it could be discussed that the correlation between parameters is due to random distributions of data. As mentioned above, the Phosphate quantity and its changes were low that this issue caused the Phosphate line, unlike other parameters, being straight.

4. Conclusions

Collection and data analysis of 9 quality variables of water along Karaj and Jajrood rivers during 2006–2008 revealed that, water quality along Karaj river is better than that of Jajrood river. Furthermore WQI had variation along two rivers, 113 and 224 stations are responsible for these variation along Karaj and Jajrood rivers respectively. Dams on this rivers cause better WQI. Water quality of two rivers varied seasonally and annually.

Results imply that on the basis of NSFWQI the best and worst quality of Karaj and Jajrood rivers occur in winter and spring respectively.

Investigation on annual variation of WQI average in three years shows that the Karaj river and the Jajrood river in 2006 have the lowest quality. Most of studied parameters of two rivers have correlation to each other; but except to DO and temperature, there is not a strong linear correlation between parameters. From all considered parameters of WQI, the phosphate quantity had no considered effects on water quality of studied rivers; however, the BOD_5 parameter had most changes.

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