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A new strategy to reduce factors number in water quality measurements using Taguchi method – case study: the Karaj River

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ABSTRACT

For water quality assessment, there are several water quality indices, such as National Sanitation Foundation-Water Quality Index (NSF-WQI). These indices are determined by measuring several parameters in different samplings. Because the value of some of the measured parameters is constant during the different samplings; hence, these parameters can be measured in the earlier samplings and be used in the later one. The identification of these parameters can reduce the time as well as the cost of water quality evaluation. In this study, a new strategy by Taguchi method was used to propose a method (proposed method) to determine the mentioned parameters in a case study of Karaj River, Iran. For demonstrating capability of this strategy, water quality was calculated by standard (NFS-WQI), adjusted, and proposed methods and then the results were compared. Nine measured parameters in standard method were reduced to four by using the proposed method. In contrast to standard and adjusted methods that showed significant differences ($p < 0.1$), there were no differences between proposed and standard method results. Therefore, the proposed method may be recommended for water quality evaluation with reduction of the cost and the time.

Keywords: Water quality index; Taguchi method; Karaj River; Surface water evaluation; WQI factors reduction

1. Introduction

Surface water is one of the essential resources for supporting sustainable development. However, rapid urbanization and industrial development during the last decade have made some serious environmental impacts, particularly on water resources [1,2]. According to Amadi et al., meeting water quality expectations for rivers is essential to protect drinking and sanitation water resources [3]. In addition, it encourages recreational activities and provides a good environment for fish, aquaculture and wildlife. Therefore, water quality evaluation and management is extremely important. Water quality of rivers in urban areas is contaminated by discharges from untreated domestic, small scale industries and agricultural run-off. Changes in physical, chemical and biological water characteristics lead to increase of water pollution level [1,3,4]. Therefore, some tools must be developed for a permanent monitoring and water quality assessment [5]. Because of mathematical modeling complexity, introducing a simple expression with minimum number of parameters is interesting [5]. Based on this approach, several indices are used for surface water quality evaluation. The Water Quality Index (WQI), the simplest of these indices, is used for water quality evaluation and water resource management [6,7]. It can be treated as a management tool that summarizes large amounts of complex data into a single number which can be calculated easily and used

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for an overall description of the quality of water bodies [8,9]. WQI is calculated by aggregating of some measured parameters such as dissolved oxygen, pH, nitrate, phosphate, and so on. Several water quality indices like Oregon Water Quality Index (OWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI) and National Sanitary Foundation Water Quality Index (NSF-WQI) are some of the river water quality indices developed by organizations and used by many researchers during the previous years [9,10]. NSF-WQI that is recognized as the forerunner of many indices is being adapted to present time [11]. NSF-WQI is determined by measurement of the nine parameters: dissolved oxygen (DO), fecal coliform (FC), pH, biochemical oxygen demand (BOD), temperature changing (T), total phosphate (TP), nitrate (NO_3^-), turbidity (Turb.), and total solids (TS) [6,11–14]. Using this index, water quality is classified as very bad (0–25), bad (25–50), medium (50–70), good (70–90), or excellent (90–100) [6,10, 14,15]. This classification can be used to suggest the type of water usages such as, drinking, irrigation, aquaculture, recreation, swimming and so on. NSF-WQI can be quickly assessed water quality in different times and/or stations of the samplings zone [15]. In most of WQIs, especially NSF-WQI, numerous of variables (at least eight) should be measured in each sampling [12]. This feature can be considered as the only disadvantage of NSF-WQI especially when evaluation carried out in a short time period. Undoubtedly, an index with a few parameters is preferred due to reduction of cost and time [13]. In addition, in many cases, it is difficult to measure all quality parameters (e.g., nine parameters for NSF-WQI) due to lack of time, testing failure or testing cost [12, 16]. Therefore, developing a new method to calculate WQI by fewer variables is interesting. There are a few studies for reduction of WQI variables. For instance, Said et al. proposed an equation which reduces WQI parameters to five, including DO, TP, turbidity, FC and specific conductivity [12]. They showed that, compared with other indexes (e.g., NSF-WQI), their method had some advantages including five variables compared with eight or more for other indices. Kannel et al. investigated three water quality indices including WQI (by 18 parameters), minimum WQI (WQI_{min}) (by 5 parameters) and WQI_{DO} (by 1 parameter) [17]. They pointed that the WQI_{min} and WQI_{DO} could be interested in developing countries because of fewer parameters and analytical cost. In addition, WQI_{min} by three parameters (TP, DO and turbidity) proposed by Simões et al. [13]. They showed that WQI_{min} may be used as a new tool for hydrographic watershed management and aquatic body monitoring. The results of their study indicate that this tool will decrease the cost of monitoring programs by reducing involved parameters. Also Koçer and Sevgili showed that WQI_{min} calculated using only NH_4^+-N and total organic nitrogen (TON) instead of a number of ineffective factors is a useful and easily applicable methodology in the assessment of the impacts of trout farm effluents on the stream water quality [5]. As another example, Lumb et al. calculated WQI_{min} using four parameters: (1) NH_4^+-N, (2) TON, (3) soluble reactive phosphorus (SRP) and (4) total organic phosphorus (TOP) concentrations [7]. They showed that WQI_{min} is a more suitable method than objective WQI for aquacultural impacts assessment. In addition, they pointed that using of NH_4^+-N and TON instead of 4 mentioned factors for WQI_{min} calculation may be reduced cost, time and effort-saving way in water quality monitoring programs. Mentioned reports show that the reduction of WQI parameters has recently been given attention. In addition to these cases, there is another approach for WQI calculation when the measured parameters are less than one which is used in standard method (e.g., nine parameters in NSF-WQI method). This approach is named adjusted method in which, the WQI is calculated from the value of available parameters and then is corrected by their weighting factors [16, 18].

In this study, a new strategy is suggested for reduction of WQI parameters using Taguchi method and capability of proposed method was evaluated in a case study of Karaj River, Iran. In this study, and by using proposed strategy base on Taguchi method, available data of pervious water quality measurements in the Karaj River were used to determine which factors could be ignored in the next sampling. Then, WQI was calculated by proposed method and compared with other conventional methods.

2. Materials and methods

2.1. Study area

The samplings were carried out in five stations (due to their importance for pollutants entrance) of Karaj River, Iran (Fig. 1) (Latitude 51° 04′N to 51° 09′N and longitude 35° 83′E to 35° 96′E). The most flow of Karaj River and its branches is applied for agricultural, municipal and industrial uses of Tehran and Alborz Province and the remaining flow enters to the Qom Salt Lake [6,15]. The Karaj surface watershed encompasses more than 5,000 km^2 with annual average precipitation of 700 mm [6,15].

2.2. Sampling and analytical procedure

Samplings and WQI calculating were carried out for 2 years (12 months for 2009–2010). The data set taken in this

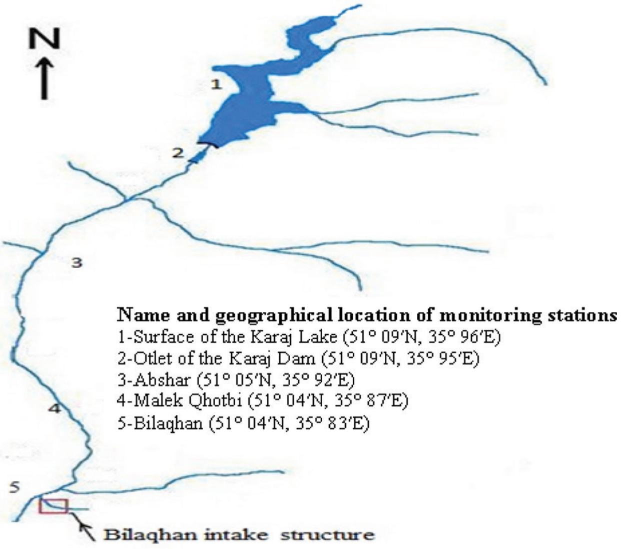

Fig. 1. Karaj River plan and sampling stations.

Table 1
Water quality parameters, units and analytical measurement methods

Parameters	Abbreviation	Units	Analytical methods	Instruments
Water temperature	T	°C	Instrumental	HACH (pH/conductivity/temperature)
pH	pH	–	Instrumental	
Dissolved oxygen	DO	mg/l	Instrumental	WTW (DO meter, Oxi 340i-WTW)
Total solids	TS	mg/l	Filtration and gravimetric	Temperature controlled oven
Phosphate	PO_4	mg/l	Ascorbic acid reduction	UV spectrophotometer
Nitrate nitrogen	NO_3–N	mg/l	Cadmium reduction	HACH (DR2500, spectrophotometer)
Biochemical oxygen demand	BOD	mg/l	5 days incubation, 20°C	BOD incubator and DO meter
Fecal coliform	FC	CFU/100 mL	Standard medium for MPN	Autoclave, incubator
Turbidity	Turb	NTU	Instrumental	HACH (2100P portable)

study was composed of 9 parameters based on the NSF-WQI method which previously presented (named as standard method in this study). Collection, stabilization, transportation, storage and analysis of the water quality samples were done based on American Public Health Association (APHA) methods [19]. The analytical measurement methods of water quality parameters and instruments used for measuring parameters are presented in Table 1.

2.3. Standard method (NSF-WQI)

In NSF-WQI method, after calculation of weighting parameters, sub-index quality of each parameter is determined based on specific charts or equation. Table 2 shows the weighting factor of each parameter [12,15,16,20]. Finally, WQI for mentioned sampling points are determined by Eq. (1) [7,15,18], where w_i, s_i and n are the unit weight, sub-index of parameters i, and number of the parameters (nine in NSF-QWI), respectively. Software which was used in this study for the sub-index and WQI calculating was obtained from Water Research Center website [21].

$$\text{NSF} - \text{WQI} = \sum\nolimits_{i=1}^{n} w_i \cdot s_i \tag{1}$$

2.4. Adjusted method

$\text{WQI}_{\text{adjusted}}$ as in Eq. (2) is used when a number of all parameters (9 for NSF-WQI) are not available [18], where m is the number of available parameters. $\text{WQI}_{\text{calculated}}$ is calculated based on these parameters by Eq. (1).

$$\text{WQI}_{\text{adjusted}} = \frac{\text{WQI}_{\text{calculated}}}{\sum\nolimits_{i=1}^{m} w_i} \tag{2}$$

2.5. Proposed method

In this method, the quality index is divided into two parts such as uniform and non-uniform WQI. Therefore, the proposed method is described by Eqs. (3) and (4) as follows:

$$\text{WQI}_{\text{proposed}} = \text{WQI}_{\text{uniform}} + \text{WQI}_{\text{non-uniform}} \tag{3}$$

Table 2
Parameters and weights factors for NSF-WQI calculation

Parameter	Weight factor
Dissolved oxygen	0.17
Fecal coliform bacteria	0.16
pH	0.11
Biochemical oxygen demand	0.11
Nitrate	0.10
Phosphate	0.10
Temperature	0.10
Turbidity	0.08
Total solids	0.07

$$\text{WQI}_{\text{non-uniform}} = \sum_{i=1}^{m} w_i \cdot s_i \text{ and } \text{WQI}_{\text{uniform}} = \sum_{i=m}^{n} w_i \cdot s_i \tag{4}$$

where $\text{WQI}_{\text{proposed}}$ is the WQI for proposed method, $\text{WQI}_{\text{non-uniform}}$ is the WQI of non-uniform factors, $\text{WQI}_{\text{uniform}}$ is the WQI of uniform factors, n is the total parameters in WQI calculating (9 for NSF-WQI) and m is the number of non-uniform factors. Other variables are presented previously.

By using Taguchi method, uniform factors will be identified. This portion of WQI is almost constant over time while $\text{WQI}_{\text{non-uniform}}$ is changing with time. Therefore, by identification of uniform and non-uniform factors by any method such as Taguchi approach, proposed strategy could be introduced and be used. By this strategy and using $\text{WQI}_{\text{uniform}}$ as constant part of WQI, measurement factors for future sampling will be reduced.

2.6. Data preparation

Nine factors (based on NSF-WQI) were considered for using Taguchi method. Minimum and maximum value of each factor in different sampling times (monthly, seasonally or yearly) was assigned as the factor levels. In this case (by nine factors with two levels), Taguchi method suggests an orthogonal array with 12 rows that is shown in Table 3. In this table, 1 and 2 is the level of minimum and maximum value of each parameter during period sampling. For example, to calculate

WQI in winter in the Station 1, the last three rows of Table 4 were used. For example, for TP, levels 1 and 2 are 0.01 (month 10) and 0.03 (month 12), respectively. For turbidity, 3.5 (month 10) and 8.5 (month 11) are as levels 1 and 2, respectively.

2.7. Data analyzing

For all stations per seasons and the whole year, signal to noise (S/N) analysis and analysis of variance (ANOVA) were carried out by Qualitek-4 software based on Taguchi approach [22]. Taguchi method is an experimental design and analyzing method which is used in many fields such as water and wastewater treatment [23, 24].

3. Results and discussion

Table 4 shows data of the sampling for the Station 1 in 2009 as a representative of all data. NSF-WQI was calculated seasonally and annually for all stations which is shown, for example, in Table 3 for Station 1 in winter (the last column). Analysis of variance was done for all stations and seasons, but statistical results of Station 1 in winter (as an example) are shown in Table 5. Among these statistical indices, the percent influence (PI) of each parameter was employed for finding which can be ignored in future experiments. The PI of each factor in Station 1 indicates that in contrast to DO and turbidity, other parameters have no significant effect on WQI variation (Table 5). In these parameters (such as pH, BOD, FC etc.), there were no differences between maximum and minimum factor's effects on WQI variation because of low PI (less than 5% as a suggestion level). Therefore, they can be ignored in the future measurements because of their uniformity over time. These factors must be used in determining WQI as $WQI_{uniform}$. Unlike these parameters, another one with PI higher than 5% (as a suggestion level) should be considered in the future, and the higher value of PI means the more

Table 3
Orthogonal array suggested by Taguchi method

Trials	Factors								
	DO	FC	pH	BOD	T	TP	NO^3	Turb	TS	NSF-WQI[b]
1	1a	1	1	1	1	1	1	1	1	82
2	1	1	1	1	1	2	2	2	2	80.3
3	1	1	2	2	2	1	1	2	2	81.4
4	1	2	1	2	2	1	2	1	1	80.1
5	1	2	2	1	2	2	1	1	1	80.9
6	1	2	2	2	1	2	2	2	2	80.5
7	2a	1	2	2	1	1	2	1	1	82.5
8	2	1	2	1	2	2	2	1	1	83.5
9	2	1	1	2	2	2	1	2	2	82.9
10	2	2	2	1	1	1	1	2	2	83.5
11	2	2	1	2	1	2	1	1	1	83.8
12	2	2	1	1	2	1	2	2	2	84.4

[a]1 and 2 are shown as the minimum and maximum levels for each parameter.
[b]NSF-WQI was calculated for 12 trials (Station 1 in winter, for example).

Table 4
Actual values of water quality measurement along Station 1 in April to March 2009

Seasons	Variables									
	Month	T (°C)	FC (CFU/100 ml)	pH –	Turb (mg/L)	TS (mg/L)	NO_3 (mg/L)	BOD (mg/L)	TP (mg/L)	DO (mg/L)
Spring	1	13	4.5	8.37	4.9	204.7	3.24	1.5	0.03	9.4
	2	13	4.5	8.44	3.3	180.8	3.4	2.4	0.05	9.5
	3	19	7.8	8.52	2.2	173.9	2.8	1.8	0.14	8.5
Summer	4	21	15	8.68	1.4	154.5	1.9	1	0.07	7.4
	5	20	23	8.38	2.4	181.7	3	1.1	0.03	7.8
	6	20	4.5	8.6	3	148.5	0.7	0.7	0.01	8.1
Fall	7	17	2	8.32	1.3	186.6	1.3	1.2	0.02	6.7
	8	13	34	8.17	5.3	200.1	2.1	0.8	0.02	6.4
	9	9	1	8.27	3.2	210.7	2.64	1.6	0.01	7.7
Winter	10	7	1	8.31	3.5	207.5	2.1	1	0.01	8
	11	7	1	8.31	8.5	212.7	2.44	1	0.02	8.5
	12	6	1	8.34	6	214.5	3.1	0.5	0.03	9

Table 5
Results of WQI analysis in winter for Station 1 by Taguchi method

Factor	DOF	Sum of squares	Variance	F-ratio	Pure sum	Percent influence
DO	1	19.8	19.8	316.9	19.7	80.1
FC	1	0.02	0.02	0.38	0	0
pH	1	0.11	0.11	1.7	0.04	0.2
BOD	1	0.96	0.96	15.5	0.90	3.7
T	1	0.02	0.02	0.38	0	0
TP	1	0.33	0.33	5.36	0.27	1.1
NO_3	1	0.85	0.85	13.58	0.78	3.2
Turbidity	1	2.42	2.42	38.86	2.36	9.6
TS	1	0	0	0.048	0	0
Others/Error	2	0.12	0.06	–	–	2.1

important of parameters. As well as for PI indicator, actual WQI of Station 1 in winter was analyzed by multivariate analysis of variance (MANOVA) for comparison. The results of MANOVA are listed in the Table 6. Based on the p-value, all of the factors except FC (which was constant) and T are not negligible and must be considered in future measurements. Therefore, this may be an apparent contradiction between the results of two ways including PI and MANOVA. For further investigation, all factors with PI less than 5% based on the proposed method (all factors except DO and turbidity base on Table 5) were removed and MANOVA was performed again. In this case, it created a strong regression by $R^2 = 0.902$ compare with $R^2 = 0.999$ of pervious regression. Adding two other factors (BOD and NO3) with 3% < PI <5% created the better regression by $R^2 = 0.992$ which is very closed to the main regression. The results of the mentioned case study area show that ignoring unimportant factors based on PI manner and by choosing a suitable range for it also leads to a good regression. Therefore, multivariate analysis and p-value index may not be applicable as a useful indicator to determine uniform factors and using of PI index is much better. Many of the researchers have used MANOVA and regression analysis to assess the correlation between WQI parameters or regression between factors and WQI results. For example, Gholikandi et al. used bi-variant correlation to delineate relationships between WQI parameters to assess water quality in Karaj and Jajrood River in Iran. They showed that the TP and T parameters had less effect on WQI changes, while FC had the most changes in the studied rivers [6]. As another example, Haque et al. applied multivariate analysis for assessment of water quality in the Hawkesbury-Nepean River (HNR) in Sydney using the Canadian Water Quality Index (CWQI) by 12 factors. They showed that not all 12 water quality parameters are significant in explaining CWQI. Their results demonstrated that 4 to 10 water quality parameters (out of 12) are significant in the regression analysis for different stations of HNR [25].

Table 6
MANOVA results of actual WQI of Station 1 in winter

Model[a]	Unstandardized coefficients		t	P-value
	B	Std. Error		
Constant intercept	92.73	4.597	20.17	0.000
DO	2.46	0.017	148.59	0.000
pH	–3.09	0.552	–5.61	0.011
BOD	–0.919	0.033	–27.76	0.000
T	0.021	0.050	0.43	0.695
TP	–11.31	0.828	–13.67	0.001
NO_3	–0.643	0.018	–34.86	0.000
Turbidity	–0.159	0.003	–47.90	0.000
TS	–0.011	0.002	–4.46	0.021
R^2	0.999	–	–	–

[a]For models with dependent variable WQI, the FC variable is constant or has missing correlations. Therefore, it will be deleted from the analysis.

For more investigation and confirmation, the PI for each season and all study stations are listed in Table 7. These results show that factors can be classified into three groups based on PI suggestion level: (1) Variables with PI greater than suggestion level (e.g., 5%) in most seasons (such as DO and FC). These factors, as non-uniform should be measured in future experiments. (2) Variables with PI less than suggestion level (e.g., 5%) (such as pH, BOD and temperature) can be considered as uniformity factors and ignored for future measurements. For these factors, previous data can be used for calculating $WQI_{uniform}$ based on proposed method, due to unchanging over time. (3) Variables with PI either greater than or less than suggestion level in different seasons such as TP, TS and turbidity. Ignoring or considering these factors needs more attention and researcher interpretation, but their measurement is recommended. Table 8 shows the PI of WQI analyzing for all Rivers stations seasonally and yearly. These results show that variation in DO and FC controlled 62%–90% of WQI changing (classified as Group 1). More consideration appears that other variables except turbidity and TP have no significant effect on WQI changing (classified as Group 2) and could be eliminated in the future samplings. The factors such as turbidity and TP classified as Group 3. In spring, five parameters (DO, FC, TP, NO_3 and turbidity) were

Table 7
Percent influence of Stations 1–5 per seasons in case study area

Factor	Station 1				Station 2				Station 3				Station 4				Station 5			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
DO	15.2	9.5	47.1	80.1	11.6	3.2	53.9	10.8	23.3	21.6	9.7	74.7	49.6	58.9	27.7	32.8	44.6	50.5	52	21.4
FC	4.4	20.8	46.6	0	52	82.1	28.4	84.1	65.2	5.7	80.9	12.4	0	16.6	60.5	11.3	31.7	41.5	39.5	72
pH	1.4	8.7	0.5	0.2	0.1	0.7	0.3	1.4	0.2	3.8	0.5	0.3	1.5	0.2	0.1	0.8	1	0.2	0.8	1
BOD	3.8	2.2	1.2	3.7	0.2	1.7	0.1	0.8	1.5	3.5	1.2	4	1.6	2.2	2.3	5	1.8	5	0.4	2.8
T	3.8	0	0	0	0.2	0	0.2	0	0.1	0	0.2	0	0	0	0	0	0.1	0	0.1	0.1
TP	69.4	15.9	0.1	1.1	35.1	10.9	0.2	0.2	0.2	37.6	0.3	0.1	1.7	2.7	0.6	2.6	1.8	1.8	0	0.1
NO_3	0.3	31	2.6	3.2	0	0.4	0.6	0.5	0.2	1	3.3	0	29.5	3.2	0.3	11.9	0.2	0.2	0.5	1
Turbidity	1.2	1.9	1.1	9.6	0.4	0.9	16.1	1.6	8.5	4.6	2.1	1	3.8	14.8	8.3	30.3	17.7	0.8	6.5	1.3
TS	0.1	0	0	0	0.3	0	0	0	0.5	21.6	0.1	7.5	3.4	0	0.1	0.4	1.1	0	0	0
Others/Error	0.4	10	0.8	2.1	0.1	0.1	0.2	0.6	0.3	0.6	1.7	0	8.9	1.4	0.1	4.9	0	0	0.2	0.3

Table 8
Percent influence of the WQI analyzing for all River stations per seasons and the whole year

Factor	Spring	Summer	Fall	Winter	Whole year
DO	38.9	36.9	35.2	52.8	41.6
FC	29.8	25.1	55	26	37.1
pH	1.2	2.1	0.6	1.1	1.1
BOD	2.3	3.8	1.3	4.7	2.8
T	0.1	0	0.1	0	0
TP	14.5	17.4	0.4	0.8	5.4
NO_3	5.1	3.9	1.4	3.3	3.2
Turbidity	6.4	6.3	5.9	8.8	7
TS	1.6	3.2	0	1.8	1.1
Others/Error	0.1	1.3	0.1	0.7	0.7

signed as Group 1 but in summer NO_3 could not be considered among this group due to its PI. DO, FC and turbidity were signed as Group 1 in fall, winter, and the whole year. In contrast to these variables that must be measured in next samplings, variables of Group 2 should be ignored in future samplings due to their uniformity over time (with PI < 5%). By using this procedure, which was named new strategy, WQI involved factors were reduced and a new method was proposed.

3.1. Applicability of the proposed method

According to actual data, WQI was calculated based on three methods including (1) standard procedure by 9 parameters (NSF-WQI), (2) adjusted procedure by ignored uniform variables and (3) by the proposed method. For applicability of purposed method, the 2010s WQI was calculated for the different seasons at Stations 1 to 5 using of three mentioned methods (Fig. 2). Based on Eq. (3), instead of 2010's data, obtained data in 2009 were used for $WQI_{uniform}$ calculation because these variables were uniform over time. Fig. 2 shows that in most cases, the amounts of WQI calculated by the proposed method were closer to the standard method than the adjusted method. Statistical analysis on the results of four seasons showed a significant difference ($p < 0.1$) between the standard and adjusted methods; whereas, there was no significant difference between the standard and proposed method results ($p = 0.55$). Therefore, the proposed method can be recommended instead of the standard method by fewer variable tests. By this strategy, in this case study, five factors were considered as uniform factors that obtained data in 2009 were used for 2010. Also four factors (DO, FC, turbidity and TP) were considered as non-uniform parameters that must be measured in next measurements. Said et al. used a different method for reduction measurement factors and reported that DO, TP, turbidity, FC and specific conductivity as the key parameters which is similar with our results [12]. In addition, Simões et al. used TP, DO and turbidity for WQI_{min} calculating to employ in the aquatic body monitoring [13]. This means, TP, DO and turbidity are important parameters and may confirm our results.

4. Conclusion

In this study, a new strategy was employed to reduce the number of variables to be tested for calculating the WQI. In this strategy, Taguchi method was used and a new method was proposed by considering PI index. Using this method in the case study of the Karaj River in Iran caused to reduce nine factors (standard NSF-WQI) to four (proposed method). By this strategy (PI index), in this case study, five factors including pH, BOD, T, NO_3, TS were considered as uniform, while four factors (DO, FC, turbidity and TP) were considered as non-uniform parameters that must be measured in the next sampling.

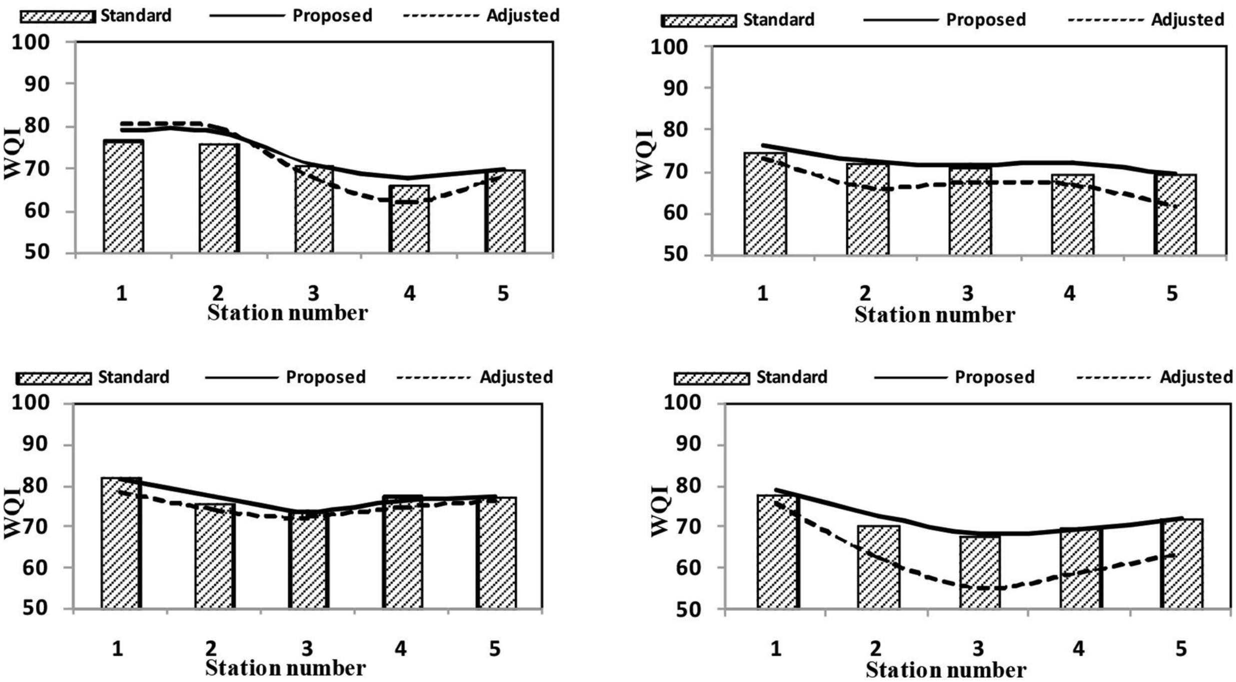

Fig. 2. Comparison WQI results of three methods in different seasons.

In addition to comparison of Taguchi method and multivariate analysis for demonstrating the capability of the proposed method, this method was compared with adjusted and standard procedure. The statistical results of the Karaj River as a case study indicate that there were no significant differences between the results of the proposed and standard method ($p > 0.55$), whereas significant differences exist between the results of the standard and adjusted method ($p < 0.1$). Therefore, this strategy and proposed method may be recommended to reduce the number of next experiments without significant differences with results obtained by standard method. Therefore, this strategy that will reduce the cost of measurements could be applied in poor and underdeveloped countries. Of course, it is recommended that by using longer term data and other statistical methods such as RSM (response surface methodology) instead of Taguchi approach, the sufficiency of this method be examined.

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