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Assessment of spatio-temporal variations of surface water quality and prioritization of pollution Sources (case Study: Talar Watershed, Mazandaran province)

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Abstract
In this study, spatio-temporal variations and prioritization of pollution sources of 12 surface water quality parameters in Talar Watershed, Iran were studied at six stations during 2003-2011 using One-way ANOVA, Principal Component Analysis (PCA), Cluster Analysis (CA) and Analytic Hierarchy Process (AHP) techniques. The results of One-way ANOVA showed that spatio-temporal variations had significant influences on water quality parameters in the study area. We observed that surface water quality parameters increased during 2003-2011 and Khatirkuh-Doab station had the maximum value and PolShahpour had the minimum value of surface water quality parameters. PCA results indicated that the first three components at Kiakola, PolShahpour, PolSefied-Talar and Paland stations; the first two components at Shirgah-Talar station; the first four components at Khatirkuh-Doab station (with the exception of the year 2006-2007 with one first component) first two components, explained spatio-temporal variation of surface water quality parameters. CA results also showed that Kiakola and Shirgah-Talar stations are placed in the first cluster, PolShahpour and Paland stations are set in the second cluster, Khatirkuh-Doab station is put in the third cluster and PolSefied-Talar station is located in the fourth cluster. The results of AHP showed that among pollution sources (lithology, land use change, land use type and mining of river bed) of surface water quality in this watershed, lithology and mining of river bed had the maximum and minimum impact on surface water quality, respectively.

Keywords: Pollution sources, Spatio-temporal variations, Surface water quality, Talar watershed

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1. Introduction

Surface waters share the highest risk of pollution due to their easy access for sewage disposal (Samarghandi *et al.*, 2007). Human activities such as urban expansion, industrial and agricultural activities have increased water resource utilization and impacted local and regional natural processes such as precipitation, erosion and weathering of crustal materials and has damaged the use of water resources for drinking, industry, and agriculture (Karbassi *et al.,* 2008; Mahavi *et al.,* 2005; Najafpour *et al.,* 2008; Nouri *et al.,* 2008; Pejman *et al.*, 2009). Rivers are the most vulnerable surface water bodies because of carrying urban and industrial wastewaters and agricultural drainage (Singh *et al.,* 2005; Wang *et al.,* 2007). In addition to contaminants, factors such as increase in water demand, higher living standards and reduction of acceptable water supplies have caused unsuitable social and environmental situations around the world (Kerachian and Karamouz, 2006). Therefore, assessment of water quality due to its direct impact on public health and aquatic marine life is important (Dixon and Chriswell, 1996).

Data which describe the spatio-temporal variations of water quality in a river could be used to represent the relative importance of natural and human impacts (Markich and Brown, 1998) and could provide dynamic information for decision makers in water resources management (Xu *et al.,* 2012). This requires a better understanding of spatio-temporal variations of water systems pollution (Bu *et al.,* 2010). Over the past decade, monitoring the quality of rivers through measuring water quality parameters has increased. Due to the spatio-temporal variations in water quality, interpreting results of such quality assessments is often difficult. Thus, a monitoring program for providing a representative way of estimating the quality of surface water, is necessary (Shrestha and Kazama, 2007; Simeonov *et al.,* 2003).

In recent years, multivariate analysis such as Principal Component Analysis (PCA), Cluster Analysis (CA) and also univariate analysis such as one-way ANOVA have been used to better assess the spatio-temporal variations of water quality parameters (Deano *et al.*, 2008; Fan *et al.*, 2013; Omoirabor *et al.*, 2008; Reghunath *et al.*, 2002; Said Muhammad *et al.*, 2010; Shrestha and Kazama, 2007; Simeonov *et al.*, 2004; Strobl and Robillard, 2008; Varol *et al.*, 2012; Wang and Xiao, 2007; Wang *et al.,* 2012; Xu *et al.,* 2012; Yung *et al.*, 2001). These techniques help better understand the spatio-temporal variations in water quality and provide an effective means for the actual management of water resources (Li and Zhang, 2010; Varol and Sen, 2009; Zhang *et al.,* 2009).

Analytic Hierarchy Process (AHP) involves a series of judgments and valuations in a logical manner. It can be said that this technique is dependent on personal imagination and hierarchical planning on the one hand logic, understanding and analysis for decision making and final judgment and on the other (Ghodsi Pour, 2006). This technique can be used to weight parameters

(Khadri *et al.*, 2010) and pollution sources of water quality (Mohammad Shafiee *et al.*, 2011). We have used multivariate analysis and AHP for water quality assessment in Mazandaran Province of Iran.

2. Methodology

2.1. Study area

Talar Watershed is located between 35° 44' 41" to 36° 19' 13" Eastern longitudes and 52° 35' 38" to 53° 23' 56" Northern latitudes which drains by a main river named Talar that stretches from south to north (Nazari, 2010). Six stations (Kiakola, PolShahpour, Shirgah-Talar, PolSefied-Talar, Khatirkuh-Doab and Paland) which have a complete data base were chosen for this study (Fig. 1).

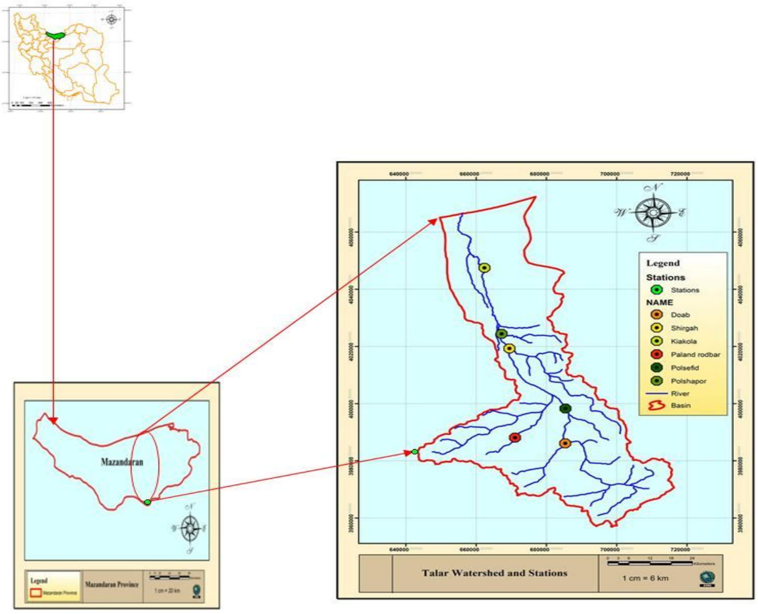


Figure 1. Geographical location of Iran, Mazandaran Province, Talar Watershed and stations

2.2. Data analysis

A total of 12 parameters of water quality including Salt Concentration or Total Dissolved Solids (TDS), Electrical Conductivity (EC), acidity (pH), Cations (Ca, Mg, Na and K), Anions ($HCO3^{-}$, Cl and SO4), Sodium Absorption Ratio (SAR) and Total Hardness (TH) at 6 stations (Kiakola, PolShahpour, Shirgah-Talar, Pol Sefied-Talar, Khatirkuh-Doab and Paland) were analyzed on a monthly basis. These parameters were measured during 2003 to 2011. The spatio-temporal variations of river water quality parameters were assessed using one-way analysis of variance in SPSS software. For detection of significant effects, the mean values were compared using Duncan test. Then, using STATISTICA software and Principal Component Analysis (PCA), the spatio-temporal variations of river water quality parameters of Talar watershed were analyzed. Afterwards, using the PC-ORD software and Cluster Analysis (CA), data on water quality monitoring stations of Talar watershed was clustered. Finally, using the Expert Choice software and Analytic Hierarchical Process (AHP) technique based on the questionnaire filled by experts, the relative importance of pollution sources of surface water (lithology, land use change, Land use type and mining of river bed) in the study area was determined.

3. Results

3.1. Spatial variations of water quality

The results of the one-way ANOVA on water quality parameters showed a significant effect of spatial variations on all parameters during the whole study period (Table 1). Results showed that Khatirkuh-Doab (upper part of the watershed) and PolShahpour (lower part of the watershed) stations had the highest and lowest amount of parameters, respectively (Figs. 2 and 3).

Spatial analysis revealed that among 12 mentioned components at Kiakola, Pol Shahpour and PolSefied-Talar stations, the three first components and at Shirgah-Talar and Khatirkuh-Doab stations the two and the four first components, respectively, represent the spatial variations of water quality (Tables 2 and 3).

Table1. Results of ANOVA for spatial response of water quality parameters in Talar watershed

Parameters	F
TDS	428.03^{***}
EC	433.4^{***}
pH	5.16^{***}
$HCO3^{-}$	22.64^{***}
Cl	312.13^{***}
SO_4	295.75^{***}
Ca	218.48^{***}
Mg	204.42^{***}
Na	322.96^{***}
K	243.49^{***}
SAR	118.25^{***}
Hardness	2.56^{***}

(***significant at $0.001 \geq P$)

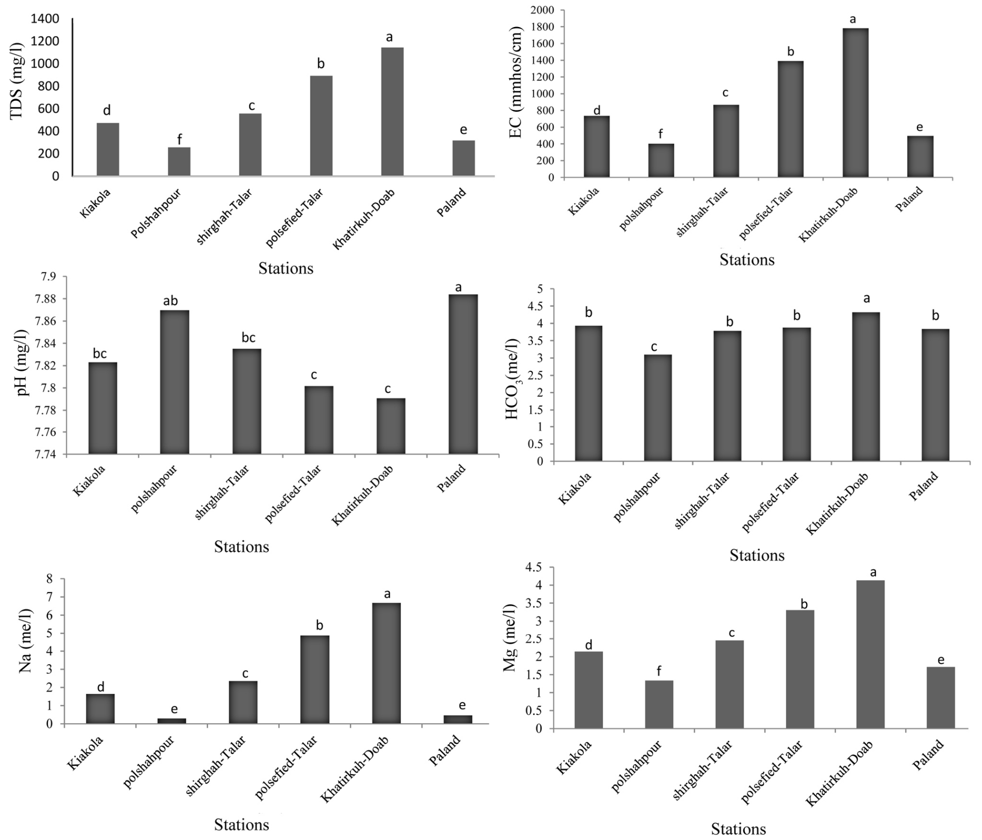
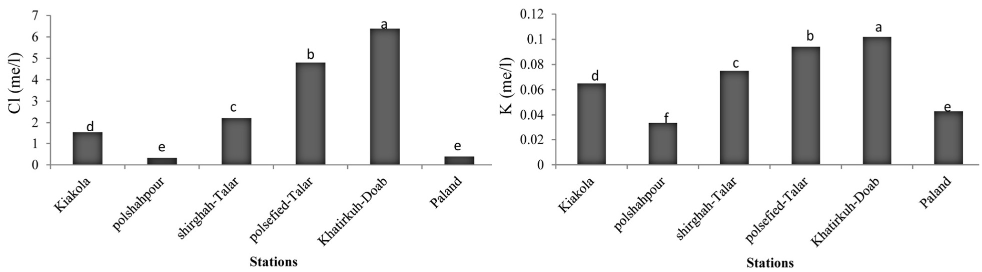


Figure 2. Means of water quality parameters in different stations in Talar Watershed



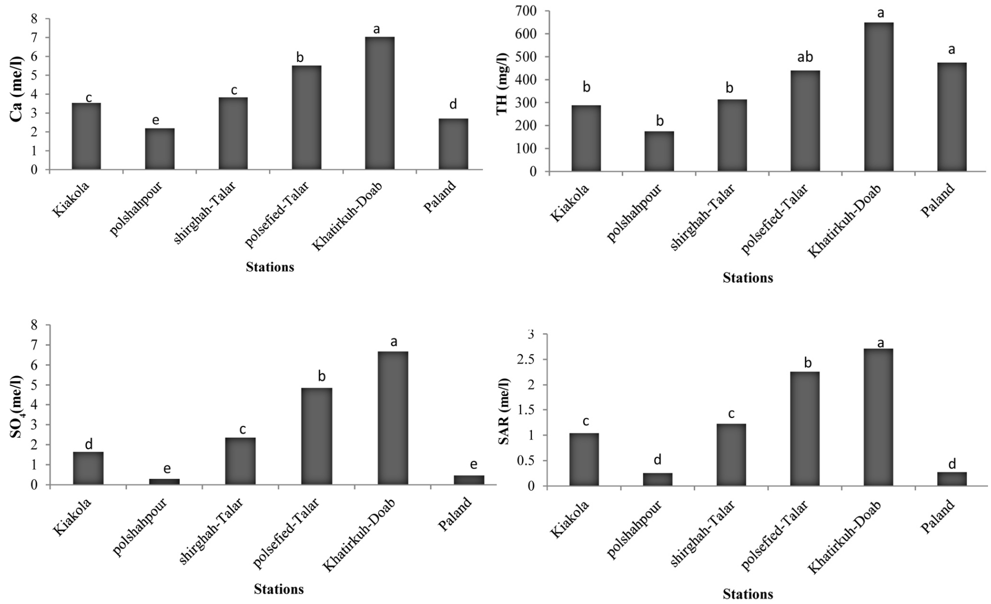


Figure 3. Means of water quality parameters in different stations in Talar Watershed

Table 2. Percentage of expressed spatial variations for main components in Talar Watershed

Component are expressed as precentage variation						
Components	Kiakola	PolShapour	Shirghah-Talar	Polsefied-Talar	Khatirkuh-Doab	Paland
1	51.21	63.66	68.80	62.94	50.08	43.90
2	19	12.63	13.05	11.38	14.70	18.54
3	12.75	8.85	7.40	8.67	11.02	14.10
4	7.62	7.57	6.19	8	10.51	8.04
5	4.44	3.82	2.85	4.22	5.67	7.76
6	2.94	2.61	1	3.29	0.51	3.31
7	1.02	0.69	0.71	1.38	2.83	2.82
8	0.76	0.13	0.1	0.06	1.48	1.30
9	0.21	0.02	0.05	0.05	0.11	0.21
10	0.02	0.02	0.02	0.01	0.06	0.02
11	0.01	0.00	0.02	0.01	0.03	0.01
12	0.00	0.00	0.00	0.00	0.01	0.00

Table 3. Comparison of water quality parameters for main components in Talar Watershed

Stations	Kiakola			PolShapour			Shirghah-Talar	
Components	1	2	3	1	2	3	1	2
TDS	-0.95	-0.28	0.01	-0.98	-0.12	0.02	-0.99	0.01
EC	-0.96	-0.27	0.02	-0.99	-0.13	0.01	-0.99	-0.02
pH	0.06	0.23	0.37	0.21	0.41	0.32	0.14	0.62
$HCO3^{-}$	-0.52	0.39	-0.57	-0.64	-0.67	0.04	-0.18	-0.84
Cl	-0.82	0.36	0.00	-0.86	0.40	0.06	-0.94	0.15
SO_4	-0.66	-0.67	0.28	-0.87	0.21	-0.05	-0.86	0.29
Ca	-0.75	-0.61	0.04	-0.87	-0.11	0.42	-0.83	-0.37
Mg	-0.73	0.13	-0.45	-0.26	-0.46	-0.80	-0.83	-0.02
Na	-0.70	0.47	0.40	-0.88	-0.39	-0.11	-0.90	0.24
K	-0.95	0.02	0.04	-0.82	-0.16	0.06	-0.93	-0.08
SAR	-0.76	0.50	0.07	-0.76	0.49	-0.21	-0.99	0.32
TH	-0.65	0.65	0.03	-0.94	-0.30	0.07	-0.99	0.01

Stations	Polsefied-Talar			Khatirkuh-Doab				Paland		
Components	1	2	3	1	2	3	4	1	2	3
TDS	-0.99	0.01	0.05	-0.97	0.15	0.07	-0.04	0.91	0. 13	0.00
EC	-0.99	0.01	0.00	-0.98	0.08	0.06	-0.06	0.98	0.05	0.00
pH	0.13	-0.23	0.68	0.17	0.35	0.84	0.09	0.16	0.02	-0.28
$HCO3^{-}$	-0.16	-0.80	0.46	-0.01	-0.33	0.10	-0.85	0.70	0.30	0.56
Cl	-0.93	0.13	-0.09	-0.93	-0.14	0.13	0.16	0.56	-0.58	-0.31
SO_4	-0.84	0.26	0.31	-0.61	0.63	-0.15	0.23	0.77	-0.14	-0.36
Ca	-0.80	-0.22	0.20	-0.65	0.61	-0.20	-0.06	0.66	0.18	-0.48
Mg	-0.74	-0.37	0.14	-0.60	0.29	0.13	-0.54	0.61	0.19	0.50
Na	-0.90	0.31	-0.17	-0.85	-0.42	0.18	0.19	0.40	-0.86	0.25
K	-0.76	-0.18	0.23	-0.66	-0.11	0.13	-0.13	0.78	0.03	0.01
SAR	-0.79	0.42	-0.25	-0.68	-0.61	0.21	0.29	0.18	-0.93	0.25
TH	-0.99	0.01	0.05	-0.97	0.15	0.07	-0.04	0.91	0. 13	0.00

According to Tables 2 and 3 on Kiakola station, the PCA technique introduces 12 components of which the first three components were the main components and explained 82.96 of the total variance in the data set. The first, second and third components show 51.21%, 19% and 12.75% of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH), (SO_4) and ($HCO3^{-}$, pH), respectively.

According to Tables 2 and 3 on PolShahpour station, the PCA technique introduces 12 components of which the first three components were the main components and explained 85.14% of the total variance in the data set. The first, second and third components show 63.66%, 12.63% and 8.85% of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Na, K, SAR and TH), ($HCO3^{-}$, pH) and (Mg), respectively.

According to Tables 2 and 3 on Shirgah-Talar station, the PCA technique introduces 12 components of which the first two components were the main components and explained 81.65% of the total variance in the data set. The first and second components show 68.60% and 13.05% of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and ($HCO3^-$, pH), respectively.

According to Tables 2 and 3 on PolSefied-Talar station, the PCA technique introduces 12 components of which the first three components were the main components and explained 82.99% of the total variance in the data set. The first, second and third components show 62.94%, 11.38% and 8.67% of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Na, K, SAR and TH), ($HCO3^-$) and (pH), respectively.

According to Tables 2 and 3 on Khatirkuh-Doab station, the PCA technique introduces 12 components of which the first forth components were the main components and explained 86.31% of the total variance in the data set. The first, second, third and forth components show 50.08%, 14.70%, 11.02% and 10.51% of the total variance in the data set, and included parameters (TDS, EC, Cl, Ca, Na, K, SAR and TH), (SO_4), (pH) and ($HCO3^-$), respectively.

According to Tables 2 and 3 on Paland station, the PCA technique introduces 12 components of which the first third components were the main components and explained 76.54% of the total variance in the data set. The first, second and third components show 43.90%, 18.54% and 14.10% of the total variance in the data set, and included parameters (TDS, EC, SO_4, $HCO3^-$, Ca, K, Mg, SAR and TH), (Cl, Na and SAR) and (pH), respectively.

3.2. Temporal Variations of water quality

The results of the one-way analysis of variance showed that the temporal effect was not significant on the river water quality parameters at Kiakola, PolShahpour, Shirgah-Talar stations (except for pH) but it was significant at Polsefid-Talar (except for Ca and SO4), Khatirkuh-Doab and Paland stations (except for EC, pH, TH, SAR and TDS) (Table 4). The general trend of temporal variations includes increase in most parameters of water quality (decreased water quality) during the period of study (Table 5).

The results of PCA technique over temporal variations showed that among 12 components, the two first components represent the temporal variations of parameters for the whole study period except for the years 2006-2007 (one factor) (Tables 6 and 7).

Table 4. Results of ANOVA for temporal response of water quality parameters in Talar Watershed

Stations Parameters	Kiakola -2011) (2003	Polshahpour (2003-2011)	Shirghah-Talar (2003-2011)	Polsefied-Talar (2003-2011)	Khatirkuh-Doab (2003-2011)	Paland -2011) (2003
TDS	1.12^{ns}	0.93^{ns}	1.5^{ns}	2.94**	8.44***	1.69^{ns}
EC	1.15^{ns}	1.15^{ns}	1.91^{ns}	2.81*	7.91***	1.84^{ns}
pH	2.77^{ns}	1.47^{ns}	6.71^{ns}	7.61***	7.46***	1.06^{ns}
$HCO3^-$	1.36^{ns}	0.89^{ns}	6.12^{ns}	1.57***	2.65*	3.11**
Cl	1.54^{ns}	2.87^{ns}	2.83^{ns}	4.41***	7.85***	6.87***
SO_4	1.3^{ns}	0.83^{ns}	0.31^{ns}	1.41^{ns}	7.77***	2.17***
Ca	1.1^{ns}	2.74^{ns}	0.29^{ns}	3.76^{ns}	8.78***	4.64***
Mg	1.48^{ns}	2.06^{ns}	0.34^{ns}	2.86*	4.76***	2.46*
Na	0.98^{ns}	1^{ns}	0.34^{ns}	2.36*	4.80***	3.25**
K	2.46^{ns}	2.01^{ns}	2.34^{ns}	6.3***	12.34***	4.16***
SAR	1.04^{ns}	1.08^{ns}	0.24^{ns}	2.29*	4.19*	3.21^{ns}
TH	1.16^{ns}	1.34^{ns}	0.12^{ns}	3.54*	74.56***	1.73^{ns}

(ns –Not significant, *significant at the level of $0.05 \geq P > 0.01$, ** $0.01 \geq P > 0.001$ and***at the level of $0.001 \geq P$)

Table 5. Means of water quality parameters, for studied stations during 2003-2011years in Talar Watershed

Parameters	Stations	2004-2003	2005-2004	2006-2005	2007-2006
TDS	Polsefied-Talar	865.58^{bc}	788.54^{bc}	855^{bc}	753.54^{c}
	Khatirkuh-Doab	1093.16^{bc}	1028.33^{bc}	1105.33^{bc}	934.5^{c}
EC	Polsefied-Talar	1325.91^{bc}	1192.63^{c}	1320.36^{bc}	1196.63^{c}
	Khatirkuh-Doab	1673.75^{ab}	1580.16^{b}	1715.33^{ab}	1469.16^{b}
pH	Shirghah-Talar	7.88^{a}	7.85^{ab}	7.89^{a}	7.89^{a}
	Polsefied-Talar	7.87^{a}	7.85^{a}	7.87^{a}	7.82^{ab}
	Khatirkuh-Doab	7.82^{a}	7.83^{a}	7.85^{a}	7.85^{a}
$HCO3^-$	Polsefied-Talar	3.84^{b}	3.24^{c}	3.56^{bc}	3.92^{b}
	Khatirkuh-Doab	4.15^{b}	4.13^{b}	4.05^{b}	4.12^{b}
	Paland	3.84^{a}	3.94^{a}	4^{a}	3.82^{a}
Cl	Polsefied-Talar	1.95^{bc}	2.07^{bc}	1.92^{bc}	1.88^{c}
	Khatirkuh-Doab	5.43^{de}	4.88^{e}	5.66^{cde}	4.9^{e}
	Paland	0.35^{cd}	0.3^{d}	0.36^{cd}	0.41^{bc}
SO_4	Khatirkuh-Doab	6.65^{b}	6.28^{b}	7.06^{b}	5.31^{b}
	Paland	0.46^{b}	0.32^{b}	0.37^{b}	0.39^{b}
Ca	Khatirkuh-Doab	7.31^{b}	6.81^{b}	6.98^{b}	5.6^{c}
	Paland	2.58^{c}	2.56^{c}	2.74^{b}	2.44^{c}
Mg	Polsefied-Talar	3.10^{b}	2.97^{b}	2.96^{b}	2.91^{b}
	Khatirkuh-Doab	3.63^{c}	3.74^{c}	3.85^{bc}	3.86^{bc}
	Paland	1.8^{abc}	1.74^{abc}	1.69^{abc}	1.81^{ab}
Na	Polsefied-Talar	4.72^{ab}	3.68^{b}	3.97^{ab}	3.84^{ab}
	Khatirkuh-Doab	5.5^{b}	5^{b}	6.05^{b}	4.96^{b}
	Paland	0.38^{c}	0.36^{c}	0.39^{c}	0.47^{ab}
K	Polsefied-Talar	0.079^{c}	0.077^{c}	0.089^{bc}	0.098^{ab}
	Khatirkuh-Doab	0.084^{c}	0.085^{c}	0.108^{ab}	0.104^{b}
	Paland	0.04^{bc}	0.39^{c}	0.044^{abc}	0.045^{abc}
SAR	Polsefied-Talar	2.31^{abc}	1.77^{c}	1.88^{bc}	1.91^{bc}
	Khatirkuh-Doab	2.33^{b}	2.17^{b}	2.59^{b}	2.25^{b}

Table 5.

Parameters	Stations	2008-2007	2009-2008	2010-2009	2011-2010
TH	Polsefied-Talar	415^{bc}	400^{c}	446^{bc}	393^{c}
	Khatirkuh-Doab	547^{cd}	527^{cd}	541^{cd}	473^{cd}
TDS	Polsefied-Talar	932.16^{abc}	897^{bc}	956.7^{ab}	1081.54^{a}
	Khatirkuh-Doab	1172.58^{b}	1178.27^{b}	1175.55^{b}	1449.91^{a}
EC	Polsefied-Talar	1492.16^{ab}	1427.27^{abc}	1511.9^{ab}	1640.45^{a}
	Khatirkuh-Doab	1889.08^{a}	1868.54^{a}	1853.88^{a}	2202.5^{a}
pH	Shirghah-Talar	7.89^{a}	7.66^{b}	7.82^{ab}	7.79^{b}
	Polsefied-Talar	7.83^{ab}	7.59^{c}	7.73^{b}	7.80^{ab}
	Khatirkuh-Doab	7.83^{a}	7.52^{b}	7.74^{a}	7.85^{a}
$HCO3^{-}$	Polsefied-Talar	3.97^{b}	4.68^{a}	3.68^{bc}	3.5^{bc}
	Khatirkuh-Doab	4.63^{b}	4.3^{b}	5.61^{a}	3.76^{b}
	Paland	4.1^{a}	3.69^{b}	4.08^{a}	3.35^{b}
Cl	Polsefied-Talar	3.11^{a}	2.07^{bc}	1.84^{c}	2.82^{ab}
	Khatirkuh-Doab	7.33^{bc}	7.54^{b}	6.73^{bcd}	9.21^{a}
	Paland	0.45^{ab}	0.35^{cd}	0.38^{bc}	0.5^{a}
SO_4	Khatirkuh-Doab	6.45^{b}	6.58^{b}	5.87^{b}	9.12^{a}
	Paland	0.47^{b}	0.42^{b}	0.34^{b}	1.15^{a}
Ca	Khatirkuh-Doab	6.7^{b}	6.73^{b}	6.87^{b}	9.17^{a}
	Paland	2.7^{cb}	2.67^{c}	3.01^{ab}	3.13^{a}
Mg	Polsefied-Talar	3.61^{ab}	3.06^{b}	3.09^{a}	3.82^{a}
	Khatirkuh-Doab	4.05^{bc}	3.91^{bc}	4.68^{ab}	5.2^{a}
	Paland	1.93^{a}	1.5^{c}	1.57^{bc}	1.57^{bc}
Na	Polsefied-Talar	5.61^{a}	5.62^{a}	5.42^{ab}	5.59^{a}
	Khatirkuh-Doab	7.79^{a}	7.79^{a}	6.73^{ab}	7.33^{a}
	Paland	0.5^{ab}	0.4^{bc}	0.35^{c}	0.4^{bc}
K	Polsefied-Talar	0.104^{a}	0.1^{ab}	0.096^{ab}	0.108^{a}
	Khatirkuh-Doab	0.111^{ab}	0.108^{ab}	0.102^{b}	0.118^{ab}
	Paland	0.05^{a}	0.039^{c}	0.041^{bc}	0.047^{ab}
SAR	Polsefied-Talar	2.64^{ab}	2.7^{a}	2.47^{abc}	2.42^{abc}
	Khatirkuh-Doab	3.38^{a}	3.41^{a}	2.81^{ab}	2.74^{ab}
TH	Polsefied-Talar	447^{bc}	419^{bc}	471^{ab}	529^{a}
	Khatirkuh-Doab	537^{cd}	1258^{a}	578^{c}	722^{b}

Table 6. Percentage of expressed annual variations for main components in Talar Watershed

Component are expressed as percentage variation								
Component	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
1	79.59	80.10	72.79	81.92	79.25	71.33	81.34	76.38
2	8.38	8.36	12.05	7.61	9.26	10.99	9.15	9.67
3	6.89	7.63	7.12	7.08	6.95	6.97	5.07	6.86
4	2.34	1.91	6.08	1.84	2.57	5.12	1.71	3.03
5	1.58	1.24	1.16	0.80	1.19	2.45	1.53	2.14
6	1.01	0.55	0.64	0.49	0.61	1.33	0.72	1.32
7	0.17	0.17	0.10	0.19	0.12	1.02	0.43	0.51
8	0.03	0.03	0.04	0.06	0.03	0.60	0.04	0.06
9	0.01	0.02	0.00	0.03	0.01	0.19	0.01	0.02
10	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Comparison of 12 parameters of water quality for main components during 2003-2011 periods in Talar Watershed

Years	2003-2004		2004-2005		2005-2006		2006-2007	
Components	1	2	1	2	1	2	1	2
TDS	-0.99	0.00	-0.99	0.00	-0.99	-0.06	-0.99	-
EC	-0.99	0.00	-0.99	0.00	-0.99	-0.07	-0.99	-
pH	0.098	-0.98	0.09	-0.99	0.11	0.13	0.37	-
$HCO3^-$	-0.52	-0.17	-0.42	0.08	-0.39	0.57	-0.53	-
Cl	-0.97	0.02	-0.98	0.02	-0.91	0.23	-0.97	-
SO_4	-0.97	0.03	-0.97	-0.04	-0.90	-0.38	-0.95	-
Ca	-0.97	-0.30	-0.97	-0.02	-0.85	-0.39	-0.97	-
Mg	-0.92	-0.02	-0.96	0.02	-0.89	0.29	-0.95	-
Na	-0.97	0.05	-0.97	0.00	-0.91	0.20	-0.96	-
K	-0.90	-0.11	-0.92	0.09	-0.96	0.03	-0.96	-
SAR	-0.94	0.05	-0.95	0.01	-0.88	0.24	-0.95	-
TH	-0.98	-0.02	-0.98	-0.01	-0.94	-0.22	-0.98	-

Years	2007-2008		2008-2009		2009-2010		2010-2011	
Components	1	2	1	2	1	2	1	2
TDS	-0.99	0.02	-0.99	-0.01	-0.99	-0.02	-0.99	-0.05
EC	-0.99	0.01	-0.99	-0.01	-0.99	-0.02	-0.99	-0.04
pH	0.33	-0.56	0.3	0.48	0.29	-0.84	0.16	-0.73
$HCO3^-$	-0.36	-0.80	-0.30	0.76	-0.62	-0.56	-0.28	-0.74
Cl	-0.97	0.13	-0.96	-0.18	-0.97	0.05	-0.98	-0.04
SO_4	-0.95	0.20	-0.96	-0.08	-0.93	0.18	-0.94	-0.01
Ca	-0.96	-0.02	-0.92	0.26	-0.96	-0.12	-0.93	-0.03
Mg	-0.93	-0.17	-0.89	0.28	-0.96	-0.06	-0.89	0.02
Na	-0.96	0.10	-0.94	-0.26	-0.97	0.05	-0.96	-0.09
K	-0.94	-0.18	-0.92	0.23	-0.91	0.06	-0.92	0. 14
SAR	-0.94	0.10	-0.52	-0.63	-0.95	0.10	-0.92	-0.05
TH	-0.98	-0.08	-0.88	-0.02	-0.98	-0.09	-0.98	-0.01

According to Tables 6 and 7 in years 2003-2004, the PCA technique introduces 12 components that two first components were the main components and explain 87.97% of the total variance in the data set. The first and second components show 79.59% and 8.38% of the total variance in the data set, which this components includes parameters of (TDS, EC, $HCO3^-$, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and (pH), respectively.

According to Tables 6 and 7 in years 2004-2005, the PCA technique introduces 12 components that two first components were the main components and explain 88.46% of the total variance in the data set. The first and second components show 80.10% and 8.36% of the total variance in the data set, which this components includes parameters of (TDS, EC, $HCO3^-$, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and (pH), respectively.

According to Tables 6 and 7 in years 2005-2006, PCA technique introduces 12 components that two first components were the main components and explain 84.84% of the total variance in the data set. The first and second components show

72.79% and 12.05 % of the total variance in the data set, which this components includes parameters of (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and ($HCO3^-$, pH), respectively.

According to Tables 6 and 7 in years 2006-2007, PCA technique introduces 12 components that the first component was the main component and explains 81.92% of the total variance in the data set and this component includes parameters of (TDS, EC, pH, $HCO3^-$, Cl, SO_4, Ca, Mg, Na, K, SAR and TH).

According to Tables 6 and 7 in years 2007-2008, PCA technique introduces 12 components that the two first components were the main components and explain 88.51% of the total variance in the data set. The first and second components show 79.25% and 9.26% of the total variance in the data set, which this components includes parameters of (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and ($HCO3^-$, pH), respectively.

According to Tables 6 and 7, in the years 2008-2009, the PCA technique introduces 12 components of which the two first components were the main components and explained 82.32% of the total variance in the data set. The first and second components show 71.33% and 10.99 % of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and ($HCO3^-$, pH), respectively.

According to Tables 6 and 7 in the years 2009-2010, the PCA technique introduces 12 components of which the two first components were the main components and explained 90.49% of the total variance in the data set. The first and second components show 81.34% and 9.15% of the total variance in the data set, and included parameters (TDS, EC, $HCO3^-$, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and (pH), respectively.

According to Tables 6 and 7 in the years 2010-2011, the PCA technique introduces 12 components of which the two first components were the main components and explained 86.05% of the total variance in the data set. The first and second components show 76.38% and 9.67% of the total variance in the data set, and included parameters (TDS, EC, Cl, SO_4, Ca, Mg, Na, K, SAR and TH) and ($HCO3^-$, pH), respectively.

3.3. Clustering the stations for water quality

Results of the CA technique showed that the water quality monitoring stations in Talar Watershed were grouped in 4 clusters, from which Kiakola and Shirgah-Talar stations, PolShahpour and Paland stations, Khatirkuh-Doab stations and PolSefied-Talar stations were placed at clusters 1, 2, 3 and 4 respectively (Figure 4).

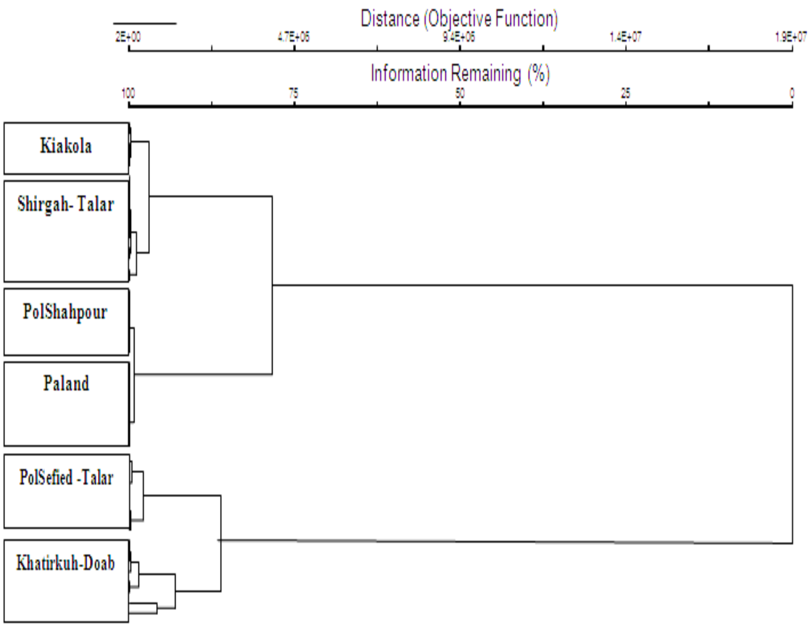


Figure 4. Dendrogram for cluster analysis of river water quality stations in Talar Watershed

3.4. Prioritization of pollution sources for water quality

The AHP technique results revealed that lithology, land use change, land use type and mining of river bed are the main sources of pollution for surface water quality in Talar Watershed. Their relative weights were 0.52, 0.23, 0.13 and 0.1, respectively (Figure 5).

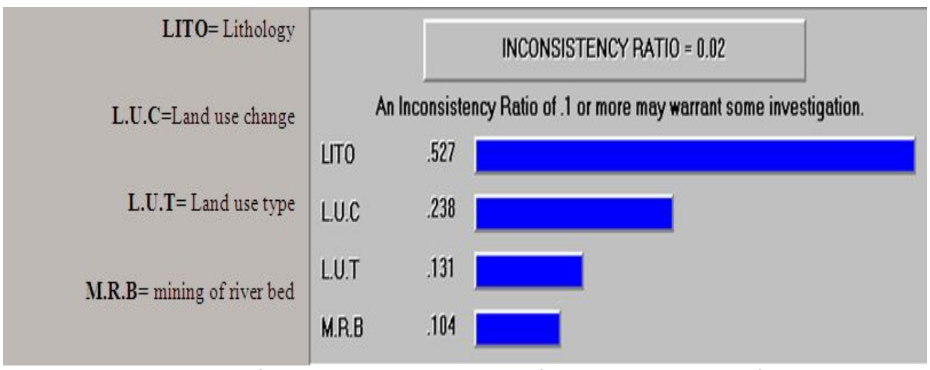


Figure 5. Comparison of the relative importance of pollution sources of water quality in Talar Watershed

4. Discussion

Considering the results mentioned in Tables 1, 2, 3 and Figs 2, 3 and geological maps (Geological and Mineral Exploration Organization of Iran, 1:100,000 maps of Gaemshahr, PolSefied and Semnan), source of spatial variations in water quality parameters in the studied area can be traced. In this regard, a close relationship between Anions, Cations, TDS, EC, SAR and TH at most stations, and Na, Cl and SAR parameters at Paland station and geology were observed. This indicates the dissolution of evaporative minerals, clay and increasing salinity levels in the river water (Heidarizad and Mohammad, 2012). The amount of pH and $HCO3^-$ parameters at Kiakola, PolShahpour and Shirgah-Talar stations reflects the presence of limestone formations and sediments entering into the river water in the form of calcium carbonate and increase pH of river water (Jodari-E-Eyvazi *et al.,* 2010). Also, significant presence of Mg at PolShahpour station probably reflects the dissolution of evaporative minerals in the sandstone and the hardness of the water (Han and Liu, 2003). The SO4 parameter at Kiakola and Khatirkuh-Doab stations reflects the presence of gypsum layers (calcium sulfate) in the formation of marl, limestone and sediments entering into the river. The amount of $HCO3^-$ parameter at PolSefied-Talar and Khatirkuh-Doab stations and pH parameter at Polsefid-Talar, Khatirkouh-Doab and Paland stations probably reflects the presence of limestone formations and sediments entering into the river water containing calcium carbonate and increase pH of river water (Jodari-E-Eyvazi *et al.,* 2010). Lithology of Khatirkuh-Doab station includes shale, sandstone, claystone, quartzitic sandstone, conglomerate; coal bearing. Lithology of Paland station includes thin to medium bedded, dark grey limestone, thin bedded shale intercalations, young alluvial fans and terraces, river terraces which are mainly cultivated. Lithology of Polsefid-Talar and Shirgah-Talar station includes young alluvial fans and terraces, river terraces that are mainly cultivated. Lithology of PolShahpour station includes conglomerate, silty marl, sandstone, siltstone and cultivated areas including old & young proluvial and fluvial fans and terraces. Lithology of Kiakola station is composed of recent loose alluvium in the river channels and cultivated areas including old & young proluvial and fluvial fans and terraces. This result is in agreement with Beihaghi *et al.,* (2012), Han *et al.,* (2010), Heydarizad and Mohammadzad (2012) and Jadairi Iuvzi *et al.,* (2010) who expressed that the water quality is mainly influenced by lithology of watershed. Also, land use type in Talar Watershed can also impact on spatial variations of river water quality parameters that are in agreement with results of Seeboonruang (2012) which stated land use type affects on spatial variations of water quality parameters.

Based on the results presented in Tables 4, 5, 6, 7 and maps of land use (images obtained from Geographical Organization of Iran and processed by ENVI and Arc GIS software) during the study period, the source of temporal variations on water quality parameters in the studied area in the form of decline in water quality and close relationship between the parameters of Anions, Cations, TDS, EC, SAR and TH in most years of study, such as pH and $HCO^{-}3$ parameters in years 2005-2006, 2007-2008, 2008-2009 and 2010-2011 which reflects the increase in pH parameter (Menico and Mas-Pla, 2008) can be due to urbanization (from 5780 to 7980 ha) and decrease in forest lands (from 83450 to 53290 ha), pasture (from 17460 to 12 600 ha) and garden-farm (from 13560 the 12430 ha) in the watershed. These findings are in agreement with results of Chessman and Townsend (2009), Hatt *et al.*, (2004), Newall and Walsh (2005) and Salajeghe *et al.*, (2011) that stated land use changes (increasing in urban land) influences on water quality. Also continuous mining of river bed in Talar Watershed (especially from upper part of the watershed) can also impact on temporal variations of water quality parameters through affecting parameters such as acidity (significant presence of pH in the years 2003-2004, 2004-2005 and 2009-2010) that is in agreement with the results of Nemati *et al.* (2010) which stated mining of river bed affect on temporal variations of water quality parameters.

Analysis of water quality monitoring stations in Talar Watershed (Fig. 4) put Kiakola and Shirgah-Talar stations in cluster 1 and PolShahpour and Paland stations in cluster 2 because of lithology of the area, defined Khatirkouh-Doab station as cluster 3 because of lithology and mining of river bed, PolSefied-Talar as cluster 4 because of urbanization. Those stations with increasing domestic, industrial and agricultural pollution were classified into distinct clusters.

Finally, results of AHP technique (Figure 5) with inconsistency ratio 0.02 (which is acceptable, Azghadi *et al.*, 2010), revealed lithology has the maximum impact and mining of river bed has the minimum impact on water quality in Talar watershed.

5. Conclusion

Results of analyzing spatio-temporal variations of water quality parameters during 2003-2011 time period showed that spatial (at all stations) and temporal (at PolSefied-Talar, Khatirkuh-Doab and Paland stations) had a significant effect on increase in most of the water quality parameters (TDS, EC, pH), Cations (Ca, Mg, Na, K), Anions ($HCO3^{-}$, Cl, SO4), SAR and TH in Talar watershed. Khatirkuh-Doab and Pol Shahpour stations had the highest and lowest amount of parameters, respectively.

Spatial variations of water quality in Talar watershed can be due to lithology and land use type. Also, temporal variations of water quality in the watershed can be brought about by factors such as land use changes and mining of river bed. Among pollution sources in Talar Watershed, lithology and mining of river had the maximum and minimum impact on water quality, respectively.

Thus, this study illustrates the usefulness of multivariate and univariate statistical techniques for analysis and interpretation of complex data sets, and in water quality assessment, understanding spatio-temporal variations in water quality management. Also, this study indicates that employed AHP techniques can combine the opinions with high accuracy and identify the overall priority of the effective variations over the pollution of water resources.

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