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Evaluation of rainwater quality using factor analysis: case study of Khorramabad in western Iran

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ABSTRACT

The objective of this study was to evaluate rainwater quality in the city of Khorramabad in western Iran for one year at four stations using specific parameters described herein. In addition, multivariate statistics are applied to determine the primary factors that affect rainwater quality as well as the relationships among the water quality parameters used in analyzing the samples. Total dissolved solids, pH, conductivity, turbidity, total hardness, carbonate and noncarbonate hardness, magnesium and calcium hardness, calcium and magnesium cations, chemical oxygen demand, nitrate, biological quality using the most probable number per 100 mL (total and fecal mpn/100 ml)and indole methyl-red Voges-Proskauer citrate (IMViC) tests were analyzed by employing standard methods. The results showed that collected rainwater had acceptable physicochemical qualities but did not meet Iranian requirements for drinking water. Approximately 62.5 and 50% of obtained samples had detectable values of total coliforms and fecal coliforms, respectively. *Klebsiella pneumuniae* was the most widely detected bacteria after the IMViC test was performed on the majority of samples. Extracted sums of squared loadings for first, second, and third components were 52.64, 18.99, and 8.7% of variance, respectively. To confirm the associations between the variables in the total data-set, cluster analyses (CA) were performed on the measured variables, which showed adequate agreement between results obtained by unsupervised factor analyses and CA, and further confirmed the conclusions about the complete data-set. We can conclude that these data-sets are valuable references for harvesting and managing rainwater, especially at the area analyzed in this study.

Keywords: Rainwater quality; Factor analysis; Cluster analysis; Microbiological quality

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1. Introduction

In current times, water shortage has become a critical global problem [1]. Growing populations, indiscriminate use of water, and continuing drought have led to water shortages in Iran and other parts of the world [2–6]. Furthermore, water shortages can intensify the problem of quality (regarding physicochemical and biological aspects) in a water supply. Certain factors such as urbanization, anthropogenic effects on the environment, and industrial activity worsen the quality of water and sometimes make it unsuitable for regular use, or sophisticated technology and expensive treatment (of waste water, for example) is required to produce reusable water. A possible solution for solving these problems is rainwater catchment [7]. Rainwater harvesting can collect and store precipitation from rooftops, rock catchments, and other surfaces by means of simple techniques and instruments [1–3,7,8]. Rainwater harvesting has been used in Asia and Africa by very old civilizations and remains a major source of drinking water supplies in rural areas [9]. Iran is a country in the Middle East, lies between 25˚00´ and 39˚47´N, and 44˚02´ and 63˚20´E. Iran has an area of 1,648,195 km^2 that, geographically, makes it the second largest country in the Middle East and 18th largest in the world. Iran has 31 provinces that are divided into more than 293 cities. Iran's total population of 77 million people makes it, demographically, the second largest country in the Middle East (after Egypt) and 17th largest in the world. Iran has a variety of weather conditions and an annual average of 250 mm of precipitation, which is 30% of the annual global average for precipitation. Because Iran is in an arid zone, approximately 65% of its territory has an arid or extremely arid climate [9].

Based on available information, we find that underground water reserves in the Middle East are under threat, including in Iran [9,10]. Current trends related to human water consumption in the region and the vast ecosystems that water supports suggest that a major crisis is imminent. In particular, Iranians have used most of their groundwater reserves [10]. The condition of groundwater has been reported to be extremely dangerous in several cities in the country [11–13]. Daily water consumption of Iranians is more than 250 L per capita and can exceed 400 L for domestic use. This is twice the world's average despite Iran's limited water availability. Rainwater has an acceptable quality regarding its softness and purity. In addition, it is a major part of the natural water cycle as well as a main source for fresh water on the planet [11]. Except for in polluted areas (contaminated by current polluting industries), rainwater quality is better than raw surface water at least in terms of its physicochemical properties [3,11,14]. Many household uses such as gardening and plant irrigation, and nonpotable uses can be satisfied by harvested rainwater that undergoes no treatment [14–17]. In Iran, the national government and water advisory boards are prepared to raise water prices as they seek recovery of the costs of providing water to the community. Therefore, using harvested rainwater can lead to reduced consumption of main water and, in turn, reduced water prices [17]. Water quality is the primary factor in rainwater development [18,19]. Microbial contamination of harvested rainwater samples, especially *Escherichia coli* and fecal coliforms, is the most common [3,20,21]. Sazakli et al. detected total coliforms, *E. coli*, and *enterococci* in 80.3, 40.9, and 28.8%, respectively, of rainwater samples harvested from the northern region of Kefalonia Island in southwest Greece. Vialle et al. [2] collected rainwater for the common domestic use of flushing toilets. Their results revealed that all samples had microbiological contamination, especially of total coliforms, *E. coli*, and *enterococci*. Similar studies such as that of Radaideh et al. indicate that harvested rainwater contains microbiological contamination [22] and is thus inappropriate for potable use without proper disinfection. Nevertheless, its use for other household purposes has been found to be permissible.

In Iran, Khorramabad governmental agencies regularly monitor public water resources based on physicochemical and biological parameters. Unfortunately, no significant interest in rainwater for use as a water resource appears to exist. Thus, no programs are in to harvest rainwater and monitor its quality. We first collected rainwater samples, then analyzed their physiochemical and microbiological qualities, then produced a data-set. Rainwater was collected during periods of rain over the course of a single year to obtain sufficient samples for analysis. Unlike in similar studies, we analyzed direct collected rainwater samples without any contact to roof. However, it can show real rainwater quality without roof interference.

2. Methods

2.1. Study area

Khorramabad is the capital of Lorestan, a province in western Iran. It has an estimated population of 350,000 based on a 2010 census report. The city is located in the Zagros Mountains and has according to Köppen climate classification, a Mediterranean climate. This means Khorramabadis much wetter than lowland cities such as Baghdad or those shielded from the

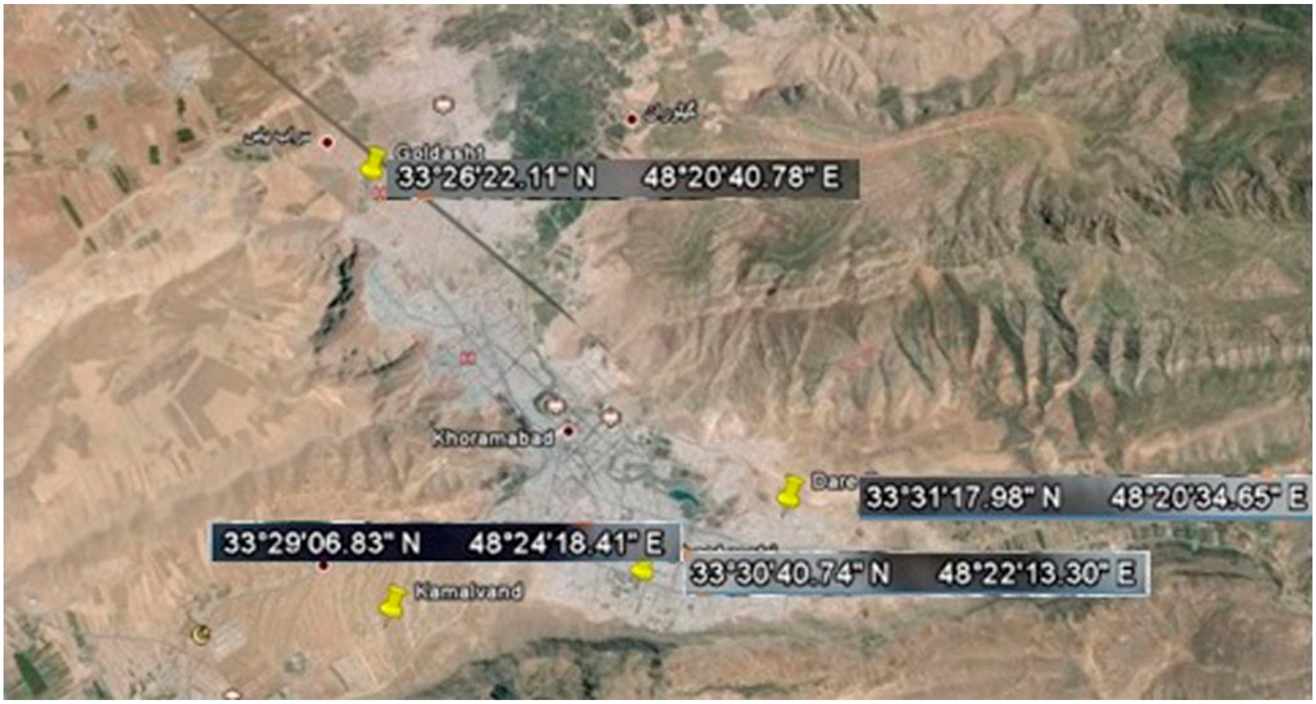

Fig. 1. Satellite images of sampling stations (Google Earth).

Zagros Mountains such as Esfahan and Tehran. At Khorramabad, the average annual precipitation is 530 mm (21 inches). By contrast, as much as 1,270 mm of rain may fall on the highest mountains. June to September is typically completely dry, but Khorramabad usually expects four inches of rainfall equivalent in December and January. In order to assess rainwater quality, sampling was performed only when rain actually fell. Rainwater samples were collected in jars at each station. The main study objectives were to collect and analyze rainwater at several stations in Khorramabad for one year (2013–2014). Information related to sampling stations, altitude, and longitude is shown in Fig. 1.

2.2. Sample collection and analysis

Water samples at each sampling station were collected by means of various project assistants and transported to laboratories according to standard operating procedures developed by the project team. Eighty samples of rainwater from four stations (Gohdasht, Kamalvand, Shatmetri, and Dare-garm, see Fig. 1) were collected and analyzed based on the quality parameters previously mentioned.

2.3. Microbiology and physicochemical parameters

Physicochemical parameters analyzed in laboratories included the water temperature at the time of sampling, pH, conductivity, total dissolved solids (TDS), and turbidity. Chemical parameters such as hardness (carbonate and noncarbonate hardness, magnesium, and calcium hardness), chemical oxygen demand (COD), nitrates, and calcium and magnesium cations were established according to standard methods for water and wastewater examination. In addition, the biological quality of the samples based on the concentrations of total and fecal coliform bacteria was reported as most probable number per 100 mL (MPN/100 mL per sample) and indole, methyl red, Voges-Proskauer, and citrate (IMViC) test [23] was conducted according to standard methods for water and wastewater examination (multiple-tube fermentation technique described in Sections 9221-B, E, F [24]. Results were analyzed and compared for the purpose of determining water quality and suitability for drinking based on Iranian national guidelines. The IMViC biochemical test has previously been used as a differential and biochemical test in other studies [25–27].

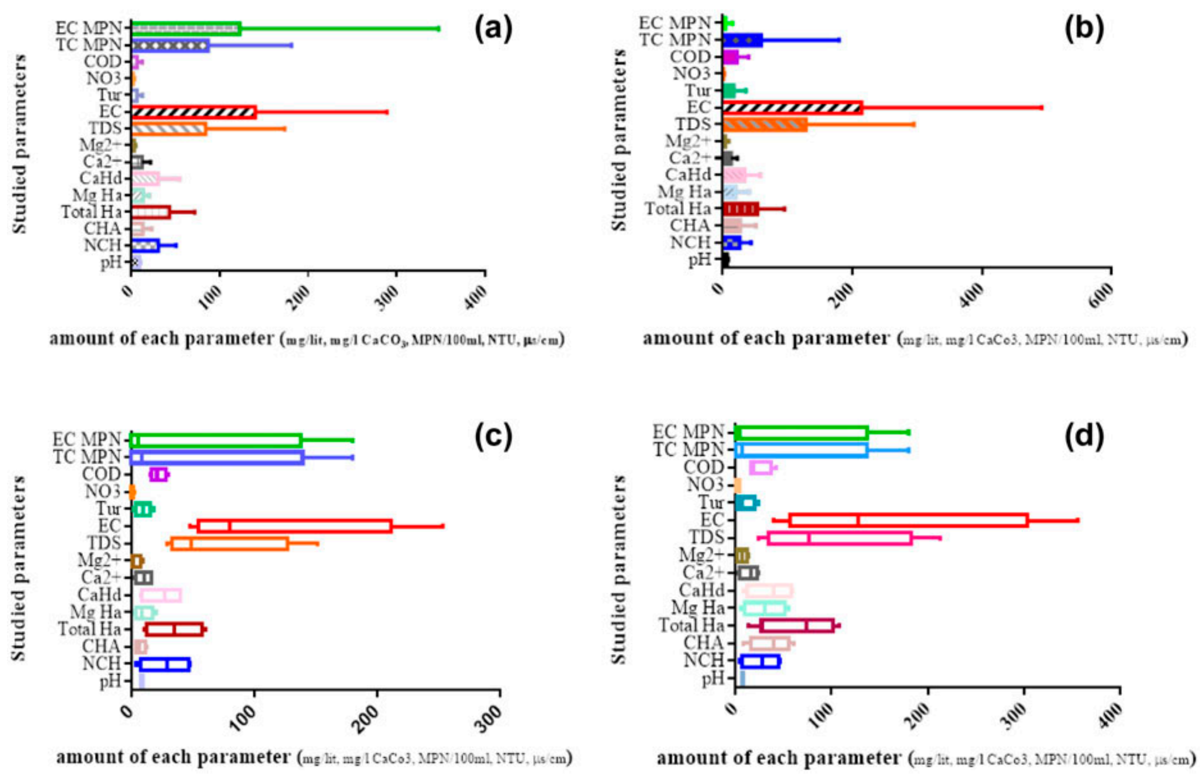

Fig. 2. Studied parameter values at rainwater sampling locations: (a) Kamalvand, (b) Shastmetri, (c) Dar-e-Garm, and (d) Goldasht.

2.4. Multivariate data analysis (factor and principal components analysis)

In extracting latent information (for example, showing related variables whose relationships are not obvious), factor analysis (FA) can be a useful tool. FA was conducted to calculate a matrix, factor loadings, and a matrix of factor scores. In addition, we conducted a residual matrix produced from an original data matrix. FA employs regression modeling methods to test hypotheses that produce errors. Principal components analysis (PCA) is a procedure of data reduction. PCA requires large data-set. In PCA, we can perform calculations as FA using raw data, correlation (if raw data are used), or a covariance matrix (variables showing their original metrics). In PCA, based on the assumption that each set of obtained data possesses no measurement errors, the total variance is analyzed based on original matrix, whereas in FA, the common variance is analyzed (Table 1).

2.5. Cluster analysis

Cluster analysis (CA) was used to identify natural groupings among objects for the purpose of discovering latent structures present in the data-set [28,29]. The dendrogram provides a visual summary of the clustering process. It presents the groups and their proximity displaying a dramatic reduction in dimensionally of the original data.

Two types of hierarchical CA agglomerative and divisive, which are used to discover clustering inside a data-set. By means of divisive methods, all obtained data migrate to one cluster, which is then divided into smaller clusters. By contrast, in agglomerative methods, each obtained data-set is contained in separate clusters; these clusters then unite to form a single cluster. The following are four of the better-known linkage algorithms used for hierarchical clustering: average, complete, single, and Ward's linkage. Ward's linkage employs an analysis of variance strategy to calculate the distances between clusters. By means of this

Table 1
Study area locations and atmospheric characteristics during rainwater sampling

Rainwater sampling series		Temperature (°C)			Wind velocity (m/s)	Relative humidity (%)	
		Max.	Min.	Raining		Max.	Min.
First	November 6–12, 2013	22	6	17	7—from southwest	68	34
Second	February 16–January 25, 2014	21	6	18	8—from southwest	85	45
Third	March 7–12, 2014	24	9	16	6—from northeast	93	57
Fourth	April 15–19, 2014	19	9	16	7—from southwest	92	59

method, the sum of squares (SS) of any two (hypothetical) clusters is minimized. Ward's linkage creates clusters of small size. ANOVA and the Kruskal–Wallis tests with significance level of 0.05 were used to do significance analysis among the sampling points to define them as the individual samples.

3. Results and discussion

The average values of measured parameters based on mean and standard deviation as well as the national standard values for drinking water are listed in Table 2.

All physicochemical parameters for the samples except turbidity comply with Iranian drinking water standards. Based on results, harvested rainwater undergoing no treatment process can be used free of worry for domestic purposes. Measured pH values were (7 ± 0.00) found to be similar to the presented value by Al-Khashman et al., while the obtained values in present study are lower than the study performed by them (77.52 vs. 165.3 for Ca^{2+} and 61.77 vs. 93.12 for Mg^{2+}). It is notable that in present study EC is higher than EC measured in study of Al-Khashman et al., although present study had lower Ca^{2+} and Mg^{2+} concentration. Ekmekyapar et al., showed positive correlations between EC and magnesium, while the significance value for EC and magnesium in present study was $p = 0.08$; there was significant correlation between EC and TDS, only. To obtain turbidity at standard usage levels by means of a settling tank or filtration process is proposed. Geological features of Khorramabad, its landscape constraints, and regional location have led to heavy automobile traffic. In addition, sandstorms and dust from Iraq have resulted in increased levels of particulate matter (PM) [30–32]. The chemical composition of PM can affect the physiochemical and microbiological composition of rainwater. Turkum et al. found correlations between the chemical compositions of PM and rainwater, especially for urban areas in Singapore, which agrees with our assumptions concerning the PM effect on the chemical and microbiological composition of rainwater [33–35]. Results show that 62.5 and 50% of samples had detectable numbers of total and fecal coliforms, respectively. Total coliforms ranged from 0 to 240 organisms per 100 mL. The highest number of total coliforms was detected at Shastmetri station (240 MPN/100 mL. For more details, see Fig. 2). Kamalvand station showed the highest fecal coliform count at 460 MPN/mL. In addition, the IMViC test was performed and probable identifications are shown in Table 3. Because of hilly geography, mild weather, and the presence of suitable pastures, animal husbandry is a main activity in Lorestan province and is the sixth largest in Iran. Parasites in this area are at high levels and travel extensively. Therefore, microbial-laced dust suspended in the air may result in microbiological contamination of rainwater.

The IMViC tests are particularly useful for differentiating *E. coli*, *Enterobacter aerogenes*, *Enterobacter cloacae*, and *Klebsiella pneumonia*. Transport of pathogenic bacteria resulting from excessive precipitation can lead to an outbreak of waterborne diseases [36,37]. We should note that, based on a monitoring program operating from 1948 to 1994, 51% of waterborne-disease outbreaks in the United States occurred because of rainfall [38].

In this study, we confirmed the number of factor specifications established by means of the varimax rotation method used to conduct orthogonal rotation. In this method, major factors were determined based on those with specification values greater than 1. Component matrices were then generated by means of orthogonal rotation using these major factors [39]. As a result of these two steps, major factors from among other factors could be selected. Results showed that three specific factors have values greater than 1 (Table 4a) and represent the major factors that affect rainwater quality. In addition, a

Table 2
Descriptive statistics for the data-set

Station	Quality parameters for rainwater in this study							
	pH	NCH[1] (mg/L $CaCO_3$)	CHA[1] (mg/L $CaCO_3$)	Total Ha[3] (mg/L $CaCO_3$)	Mg Ha[4] (mg/L $CaCO_3$)	Ca Ha[5] (mg/L $CaCO_3$)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)
Goldasht	8.3 ± 1.19	26.75 ± 20.15	37.4 ± 21.28	67.5 ± 39.4	30.75 ± 24.92	36.75 ± 24.12	14.7 ± 9.65	7.5 ± 5.3
Dar-e-Garm	8.68 ± 0.75	27.5 ± 20.93	7 ± 3.82	35 ± 23.8	9.75 ± 7.4	25.25 ± 17.26	10.1 ± 6.9	3.6 ± 4.15
Shastmetri	7.67 ± 1.88	27 ± 17.4	27.5 ± 17.4	54.5 ± 41.8	20 ± 21.2	34.5 ± 24	13.8 ± 9.6	4.88 ± 5.19
Kamalvand	8.93 ± 1.67	30.5 ± 20.09	12.75 ± 10.17	43.25 ± 28.44	13.25 ± 6.99	30 ± 24.5	12 ± 9.8	3.22 ± 1.72
IR standard	6.5–9	–	–	500	–	–	300	30

Station	Quality parameters for rainwater in this study						
	TDS (mg/L)	Conductivity (µs/cm)	Turbidity (NTU)	NO_3^- (mg/L)	COD (mg/L)	Total coliforms (MPN/100 ml)	Total fecal coliforms (MPN/100 ml)
Goldasht	97.66 ± 81.46	162.77 ± 135.77	10.11 ± 10.17	2.7 ± 1.97	23.85 ± 12.4	48.25 ± 87.9	47.25 ± 88.6
Dar-e-Garm	69.21 ± 55.85	115.35 ± 93.1	9.38 ± 6.75	0.9 ± 1.01	21.7 ± 6.52	49.25 ± 87.53	49.25 ± 87.5
Shastmetri	129.05 ± 166.27	214.97 ± 277.215	17.77 ± 18.64	1.77 ± 1.85	22.9 ± 17.85	60 ± 120	5.25 ± 10.5
Kamalvand	84.04 ± 89.4	140.07 ± 149.06	6.34 ± 6.24	2.2 ± 1.4	6.66 ± 5.6	87 ± 94.22	122.75 ± 224.9
IR standard	1,500	180–1,000	5	50	–	0	0

Notes: Noncarbonate hardness, (2) carbonate hardness, (3) total hardness, (4) magnesium hardness, (5) calcium hardness.

Table 3
Probable bacteria identification based on IMViC test result

Station	Rainfall sampling series	Probable identification by IMViC test
Goldasht	1th	*Citrobacter freundeii, Proteus mirabilis, S. paratyphi B, Klebsiella ozaenae, Citrobacter, Arizona, Erwinia, Klebsiella pneumuniae*
	2th	*All indices were negative*
	3th	*All indices were negative*
	4th	*Citrobacter freundeii, Proteus mirabilis, S. paratyphi B, Klebsiella ozaenae, Citrobacter, Arizona, Erwinia, Klebsiella pneumuniae*
Dar-e-Garm	1th	*Klebsiella pneumuniae*
	2th	*Klebsiella pneumuniae*
	3th	*All indices were negative*
	4th	*Klebsiella pneumuniae*
Shastmetri	1th	*All indices were negative*
	2th	*All indices were negative*
	3th	*All indices were negative*
	4th	*Klebsiella pneumuniae*
Kamalvand	1th	*K. axytoca*
	2th	*C. koseri/diversus, Atypical Enterobacter cloacae*
	3th	*C. koseri/diversus, Atypical Enterobacter cloacae*
	4th	*C. koseri/diversus, Atypical Enterobacter cloacae*

Table 4a
Results of factor analysis and variances

	Initial Eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.897	52.645	52.645	7.897	52.645	52.645	7.761	51.739	51.739
2	2.849	18.990	71.636	2.849	18.990	71.636	2.620	17.469	69.208
3	1.306	8.706	80.341	1.306	8.706	80.341	1.670	11.133	80.341
4	0.990	6.601	86.942						
5	0.760	5.068	92.010						
6	0.576	3.840	95.850						
7	0.297	1.978	97.828						
8	0.172	1.147	98.975						
9	0.096	0.638	99.613						
10	0.048	0.319	99.931						
11	0.010	0.067	99.998						
12	0.000	0.002	100.000						
13	5.153E−006	3.435E−005	100.000						
14	4.796E−008	3.198E−007	100.000						
15	2.818E−017	1.878E−016	100.000						

Note: Extraction method: principal component analysis.

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was assigned to a data-set. The KMO value of this study is 0.714, which is suitable for FA. In addition, the chi-square distribution (X^2) of Bartlett's test of sphericity attained a significant level and thus was suitable for FA.

Table 4b
Matrix of water quality factor loading for the rain water samples

Parameters		Factor		
F1	pH	1	2	3
	NCH	**−0.851**	0.206	0.271
	CHA	**0.769**	0.363	0.306
	Total Ha.	**0.885**	0.126	−0.027
	Mg Ha.	**0.942**	0.252	0.119
	Ca Ha.	**0.886**	−0.097	−0.077
	Ca^{2+}	**0.791**	0.477	0.251
	Mg^{2+}	**0.89**	−0.108	0.029
	TDS	**0.93**	−0.123	−0.020
	EC	**0.929**	−0.123	−0.020
F2	Tur.	0.091	**−0.778**	0.131
	NO_3	−0.189	**0.725**	−0.375
	COD	0.389	**0.619**	−0.135
F3	TC MPN	0.135	−0.561	**0.750**
	FC MPN	−0.099	−0.185	**0.784**

Notes: Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalization.
[a]Rotation converged in eight iterations.

The column labeled "Extraction Sums of Squared Loadings" indicates that the eigenvalues of factor variance are greater than 1. Extraction sums of squared loadings for first, second, and third components were 52.64, 18.99, and 8.7% of variance, respectively. The column labeled "Rotation Sums of Squared Loadings" shows a set of values derived from the rotation. Three components are capable of variance. The obtained components were rotated by means of the varimax rotation method; the first, second, and third components had 51.74, 17.47, and 11.13% of variance, respectively. Therefore, the three factors describe 80.34% of variances for the data set. The following table (Table 4b) shows the contributions of each variable to the components. The 80.43% indicates the ability of determined components to explain the variance of the studied variables and to evaluate the appropriateness of the variables for FA. Each variable is placed in the component with which it has a highly significant correlation. The first component (F1) consist of pH, non-carbonate hardness, carbonate hardness, total hardness, magnesium hardness, calcium hardness, Ca^{2+} cation, Mg^{2+} cation, TDS, and EC with a total variation of 57.73%, as shown in Tables 4a and 4b.

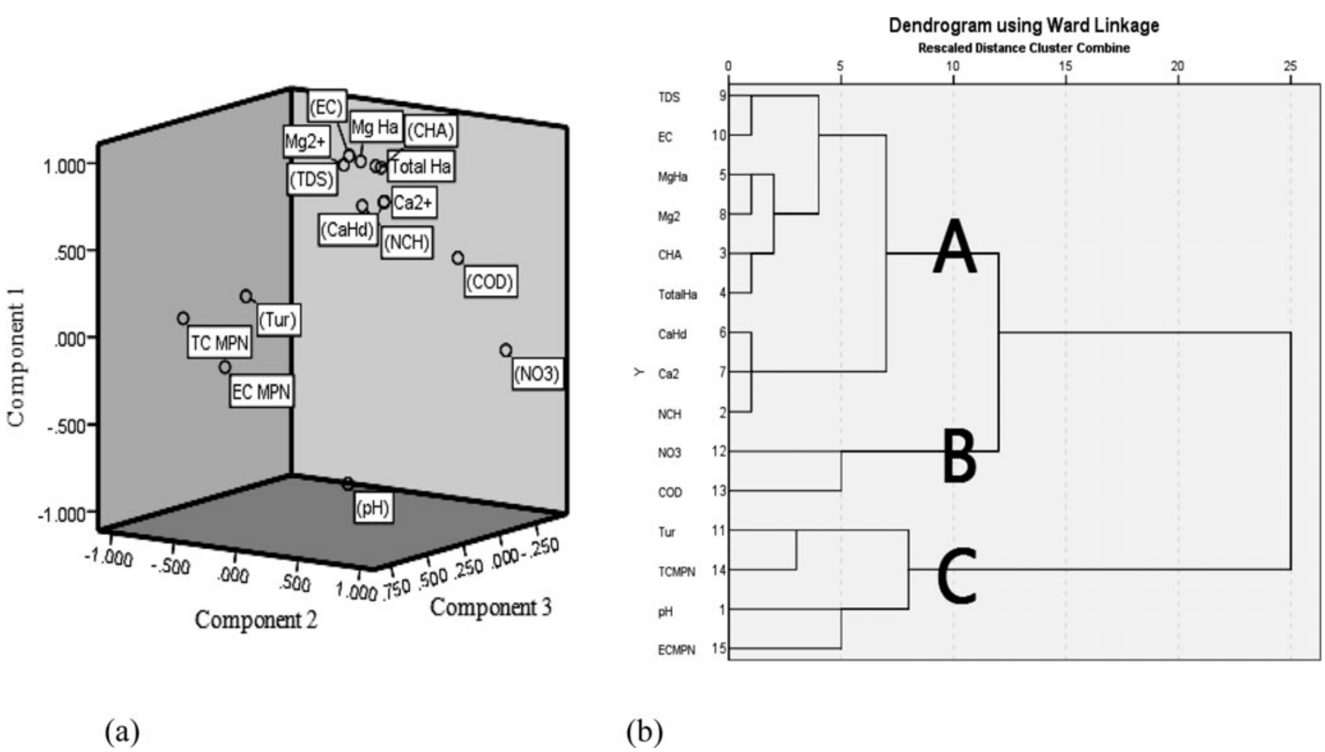

Fig. 3. (a) Three-dimensional plot of all variables in the F1, F2, and F3 components and (b) dendrogram obtained by applying the Ward linkage method.

Table 5
Correlation coefficients for the studied parameters of rainwater samples (significant at the 1 and 5% levels)

	pH	NCH	CHA	Total Ha.	Mg Ha.	Ca Hd.	Ca^{2+}	Mg^{2+}	TDS	EC	Turbidity	NO_3	COD	TC MPN	FC MPN
pH	1														
NCH	−0.57*	1													
CHA	−0.62**	0.55*	1												
Total Ha.	−0.67**	0.84**	0.91**	1											
Mg Ha.	−0.67**	0.52*	0.91**	0.85**	1										
Ca Hd.	−0.52*	0.92**	0.72**	0.91**	0.56*	1									
Ca^{2+}	−0.52*	0.92**	0.71**	0.90**	0.54*	1.00**	1*								
Mg^{2+}	−0.67**	0.59*	0.82**	0.83**	0.94**	0.57*	0.56**	1*							
TDS	−0.88**	0.67**	0.74**	0.79	0.77**	0.64**	0.64**	0.78**	1**						
EC	−0.88**	0.67**	0.74**	0.79**	0.77**	0.64**	0.64**	0.78**	1.00**	1**					
Turbidity	−0.12	−0.16	0.02	−0.04	0.10	−0.15	−0.15	0.14	0.05	0.04	1				
NO_3	0.23	−0.05*	0.03**	−0.009**	−0.12**	0.08*	0.07	−0.21*	−0.27**	−0.27**	−0.56**	1*			
COD	−0.19*	0.35	0.46*	0.46**	0.26*	0.52**	0.52*	0.35	0.27*	0.27**	−0.35*	0.29**	1*		
TC MPN	−0.06**	0.14*	0.03	0.07**	0.07**	0.06**	0.06**	0.16*	0.15	0.15**	0.62**	−0.62**	−0.41**	1*	
FC MPN	0.28**	−0.06**	−0.03**	−0.07	0.009**	−0.12**	−0.12**	0.08**	−0.009**	−0.007	0.02**	−0.35**	−0.18**	0.58**	1**

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

Total hardness has the highest loading extent of 0.942. Total hardness is the hardness of the mineral content of water and which is irreversible by boiling. High hardness can result in abnormal cloudiness and scaly formations. Levels of hardness considered too low cause water to become corrosive and aggressive. The second component (F2) consisting of turbidity, nitrates, and COD accounted for approximately 18.99%of the total variance. The third component (F3) consisting of total and fecal coliform accounted for approximately 8.7% of the total variance of the data-set. A three-dimensional plot of all variables in the F1, F2, and F3 components is shown by Fig. 3(a).

Nitrates in rainwater are an important anion that may affect ground and surface water nitrate values [40,41]. Nitrates may transfer from the air to various water sources (lakes, ground, and surface water) by means of rainwater [42]. Ammonium and nitrate presence in rainwater, PM, and ambient nitric acid are the means by which nitrogen atmosphere deposit to the earth [40,42]. Vehicles, power plants, and other industries that burn fossil fuels are the main sources for atmospheric NO and NO_2 (which form atmospheric nitrate through the oxidation process) in urban area [42]. In our study, the lowest and highest mean concentrations of nitrate ions were 0.1 and 4.4 mg/L, respectively, which are similar to that found in data from other countries (China = 1.94, India = 2.26, Romania = 3.62, Jordan = 4.17) [14,43–45]. Ekmekyapar et al., measured TKN and ammonium instead of nitrate and nitrite. In present study mean measured value for nitrate was 12.4 mg/L, while maximum reported value by Ekmekyapar et al., for TKN was 13 mg/L for one 10 sampling station and in the others was as low as 6> mg/L. They concluded organic nitrogen contribution in the samples.

To confirm the associations among variables in all data-sets, CA was performed on the measured variables. The search for natural groupings among variables was a complementary method for studying the latent structure of the data and enabled a comparison of FA results. When CA was applied, the dendrogram

Table 6a
ANOVA test to do significance analysis among the sampling points

	Sum of squares	df	Mean square	F	Sig.
pH	3.589	3	1.196	0.569	0.646
NCH	36.188	3	12.063	0.031	0.992
CHA	2,300.668	3	766.889	2.611	0.100
Total Ha.	2,388.188	3	796.063	0.681	0.580
Mg Ha.	1,025.688	3	341.896	1.321	0.313
CaHd	311.250	3	103.750	0.202	0.893
Ca^{2+}	49.800	3	16.600	0.202	0.893
Mg^{2+}	44.915	3	14.972	0.792	0.521
TDS	7,809.287	3	2,603.096	0.229	0.874
EC	21,635.737	3	7,211.912	0.229	0.875
Tur	283.563	3	94.521	0.705	0.567
NO_3	6.982	3	2.327	0.905	0.467
COD	791.916	3	263.972	1.926	0.179
TC MPN	3,910.250	3	1,303.417	0.135	0.937
EC MPN	28,702.000	3	9,567.333	0.577	0.641

Table 6b
The Kruskal–Wallis test to do significance analysis among the sampling points

Parameters	pH	NCH	CHA	Total Ha.	Mg Ha.	CaHd	Ca^{2+}	Mg^{2+}
Chi-square	1.472	0.367	6.175	1.819	2.780	1.057	1.057	2.074
df	3	3	3	3	3	3	3	3
Asymp. sig.	0.689	0.947	0.103	0.611	0.427	0.787	0.787	0.557
Parameters	TDS	EC	Tur	NO_3	COD	TC MPN	EC MPN	
Chi-square	0.188	0.188	2.144	2.939	5.639	0.764	1.761	
df	3	3	3	3	3	3	3	
Asymp. sig.	0.979	0.979	0.543	0.401	0.131	0.858	0.623	

(Fig. 3(b)) showed three clusters, which we labeled A, B, and C. The dendrogram also shows distance from 1 to 25. This means that the optimal maximum value is within the scaled distance in which the value is equal to or greater than 14.28. This results in the formation of two groups. Adapting the similarity (or results differences) of these three clusters with the three factors can be explained. Cluster A represents the pH, NCH, CHA, total hardness, magnesium hardness, calcium hardness, TDS, EC, calcium and magnesium cations, that were previously described as the F1 in FA. Cluster B contains turbidity, NO_3^-, and COD that are similar to that obtained in F2 by FA. Cluster C is the same as F3 and includes MPN/100 mL of total and fecal coliforms. Adequate agreement exists between results obtained by unsupervised FA and CA and thus confirms our conclusions regarding the complete data-set. We examined the correlation matrix of water quality parameters obtained from the analyzed rainwater. The relevant data for rainwater quality parameters (Table 5) show strongly significant correlation among all parameters for each cluster (A, B, and C). This indicates that all parameters share a common origin. The Pearson correlation coefficient indicates the strength of the linear relationship between the two variables. However, in general, its value does not completely characterize their relationship. Ekmekyapar et al., in their study showed positive correlation for EC and magnesium, only [46]. It is not in accordance with the result of the present study. According to Tables 6a and 6b there was no significant difference among sampling points for studied parameters.

4. Conclusion

FA and CA showed agreement regarding the data structure. Based on FA results, three factors were recognized, the obtained components of which (F1, F2, and F3) accounted for 51.74, 17.47, and 11.13% of variance, respectively, and a cumulative variance of 80.34%. We can conclude that more than 50 and 37.5% of rainwater samples had microbiological contamination, based on coliform and MIViC tests, respectively. In general, Iranian standards for drinking water are met with respect to physicochemical parameters. However, because of bacterial contamination and turbidity, a system to reduce turbidity and disinfect water must be employed.

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Abbreviations

TDS	—	total dissolved solids
Tur.	—	turbidity
TH	—	total hardness
CH	—	carbonate hardness
NCH	—	noncarbonate hardness
Mg Ha.	—	magnesium hardness
Ca Ha.	—	calcium hardness
TC	—	total coliform
FC	—	fecal coliform
MPN	—	most probable number
IMViC	—	indole, methyl red, Voges-Proskauer, and citrate
FA	—	factor analysis
PCA	—	principal components analysis
CA	—	cluster analysis

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