Classification of Some Spring Waters in Erbil Governorate Using Different Methods

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Abstract. This study was conducted during 2020. The water samples were taken on June and October 2020 which were represent wet and dry season respectively from 22 springs in Erbil governorate. Some water chemical properties and heavy metals were determined at both wet and dry season, the studied spring waters were classified according to some systems or methods such as classes depending on restriction of use, irrigation water quality index, cluster analysis and principal component analysis. In general, the results depending on the mentioned methods of classifications had similar results. The water for 12, 8 and 2 springs had none restriction, slight to moderate and severe restriction of uses at wet season respectively, while in dry season the water for 9, 9 and 4 springs had None restriction, slight to moderate and severe restriction of uses respectively due increase in water EC values in dry season in comparing with wet season. Depending on IWQI values using all the studied water parameters the water for 15 and 7 springs had excellent and good class respectively, while depending on IWQI for EC only the water for (13,5 and 4) springs in wet season and the water for (12,4 and 4) springs in dry season had excellent, good and poor classes respectively. The cluster analysis and principal component analysis also classified the spring water samples into three classes also.

1. Introduction
Water is regards as the most important and valuable natural resource on our planet. Water plays a vital role in the development of most economical and agricultural sectors [2 and 3]. In the Kurdistan region, the sources of water for different uses include groundwater, rivers, dams, ponds, wells, and springs. Springs are the primary source of water for agricultural and nonagricultural uses in most villages in the Kurdistan region. Although most of spring water have high-quality due to its filtration through the soil horizons, their quality relies on chemical composition and physiochemical properties [4], the wells and springs are one of the water sources for different uses [5].

The quality and quantity of the spring water is differing depending on the geological formation and environmental factors of the studied area [6]. The large basin of groundwater is existing in Erbil governorate in comparing with the area of groundwater basin in other governorates which equal to more than (5000 km²) and the number of drilled wells is (9805) wells [7]. The farmers in Kurdistan region are depending mainly on groundwater for irrigation and agricultural uses due to shortage or absenting irrigation projects in Kurdistan region and construction of numerous dams on Tigris and Euphrates in the riparian nations. Hameed[8] showed the development of the Kurdistan basins, which differentiate it from other basins is attributed to their unique features, such as its geologic structure, stratigraphic relationships, and the geomorphological setting of the region.

United nations[9] showed that in 1950, the population of the world was 2.5 billion; 4.9 billion in 1985, 6.3 billion in 2000, and 2025 will be 8.5 billion. These increase in the world population will require raises in agricultural production in order to maintain the present level of food intake, and it also require an increase in suitable water for irrigation and drinking purpose.

Water quality index is a type of mean derived by depending on numerous parameters and combining them into a single number. A WQI obtains by combining some sub-indices of water quality variables.
At last decade, the irrigation water quality index (IWQI) was widely used to identify the groundwater suitability for irrigation purposes. IWQI is a very clear tool for communicating the information on irrigation water quality. IWQI which is a specified method was developed primarily by [10]. The principal component analysis (PCA) can change and reduce multiple parameters into the most effective factors, each factor includes all parameters with different p-values. Kannel[11] indicated that the most common unsupervised methods of multivariate analysis for classification are cluster analysis (CA) and principal component analysis (PCA). Cluster analysis is a group of multivariate techniques whose primary goal is to assemble aims based on their properties [12]. The factor loadings of each member of data set on principal component are taken into account to cluster the water sample into appropriate group. The number of recorded clusters prepends on the basis of variability % explained (PCA) tool. Numerous studies were conducted in Iraq and Kurdistan region on ground water quality by [13, 14, 15, 16, 17and 18], but non or little of them depended on different tools for classification for these reason this study was conducted in order to limiting water quality or classes depending on global system classification such as Ayres and Wetcost classification, using IWQI, using PCA and CA tools.

2. Materials and Methods

2.1. Study area and water sampling

The study was conducted during the dry and wet season of 2020, the samples were taken from (22) springs in Erbil governorate, Iraqi Kurdistan region. Table (1) shows the GPS reading of the studied springs.

Table 1. GPS reading of the studied springs(locations)

| Springs | Locations              | Latitude          | Longitude         | Attitude   |
|---------|------------------------|-------------------|-------------------|------------|
| S1      | Haji omarani sarw      | 36°40′33.79″N     | 45°02′42.16″E     | 1794.95    |
| S2      | Kani graw 1/ Haji omaran | 36°40′36.97″N     | 45°01′51.74″E     | 1682.00    |
| S3      | Kani graw 2/Haji omaran | 36°40′36.97″N     | 45°01′51.52″E     | 1682.01    |
| S4      | Kani graw 3 Haji omaran | 36°40′37.15″N     | 45°01′51.29″E     | 1681.02    |
| S5      | Kani asn / Rayat       | 36°40′45.51″N     | 44°58′58.85″E     | 1464.53    |
| S6      | Qasre                  | 36°33′16.08″N     | 44°49′31.76″E     | 1100.40    |
| S7      | Bddayzan               | 36°36′49.32″N     | 44°55′13.37″E     | 1394.50    |
| S8      | Kani badlian(kani zheriy) | 36°42′06.86″N     | 44°32′09.31″E     | 724.48     |
| S9      | Kani swara             | 36°45′31.76″N     | 44°35′35.42″E     | 1464.79    |
| S10     | Kome alman             | 36°35′22.89″N     | 44°32′28.77″E     | 717.53     |
| S11     | Sarwhchawai/ Doli akoyan | 36°32′56.39″N     | 44°32′40.96″E     | 981.79     |
| S12     | Kani matkan            | 36°33′03.28″N     | 44°33′41.13″E     | 836.24     |
| S13     | Kani gorangi           | 36°33′30.63″N     | 44°33′24.97″E     | 799.88     |
| S14     | Kani mala nabi         | 36°36′04.61″N     | 44°29′50. 2″E     | 825.88     |
| S15     | Kani majidawa (Balakian) | 36°56′39.67″N     | 44°50′24.79″E     | 561.89     |
| S16     | Kani maran             | 36°37′41.87″N     | 44°28′09.1″E      | 520.95     |
| S17     | Kani bnawea            | 36°31′23.98″N     | 44°27′02.57″E     | 836.67     |
| S18     | Nawkandani xwarw       | 36°27′05.71″N     | 44°14′48.36″E     | 744.31     |
| S19     | Zebarok                | 36°28′04.92″N     | 44°13′46.79″E     | 894.43     |
| S20     | Kani graw              | 36°31′56.05″N     | 44°10′34.95″E     | 624.28     |
| S21     | Khatibian/ Kani shink  | 36°28′26.57″N     | 44°19′13.04″E     | 633.43     |
| S22     | Kani gomatal           | 36°08′46.52″N     | 44°25′37.17″E     | 772.10     |

Water samples were collected from (22) springs as mentioned before, the water was taken by using plastic bottle of 500 ml. The water samples were kept in refrigerator at (4 oC) with adding two drops of toluene to each bottle until analysis to prevent microbial activities.

2.2. Chemical analyses:
The chemical analyses of water samples were performed as follow:
2.2.1. Electrical conductivity (EC) and hydrogen ion potential (pH) of the water samples were recorded at the site by using EC and pH meter Model (HI 9814).

2.2.2. Cations (Ca2+, Mg2+) and (Na+, K+) were determined by titrimetric method using EDTA disodium salt (0.02M) according to [19] and using flame photometer model (JENWAY PF P7), as described in [20] respectively.

2.2.3. (CO32-, HCO3-, (Cl-), (NO3-N) and (SO42-) were determined according to [20].

2.2.4. Heavy metals: The heavy metals (Fe, Pb, Mn and Zn) were determined by Atomic absorption spectrophotometer.

2.3. Calculating Irrigation water quality index (IWQI)
The main steps for determining IWQI was summarized by [21] as follow:

1. Calculating the deviation from the reference values for each variable, considering normal distribution of data, the Z-test was applied for data standardization as follow:

\[ Z_i = \frac{(X_i - \bar{X})}{SD} \]  

Where:
- \(Z_i\) = Standardized value of the studied parameter.
- \(X_i\) = Value of the property determined at the water source.
- \(\bar{X}\) = Mean value of the variable evaluated from the reference population.
- SD = Standard deviation of the parameter determined from the reference population.

2. Calculating the IWQI for the studied parameters such as (Ca2+, Mg2+, Na+, K+, Cl-, HCO3- +CO32-, SO42+, and NO3-) by using the following equations:

\[ WQI_i = \sqrt{\frac{1}{N} \sum_{i=1}^{N} Z_i^2} \]  

Where:
- \(WQI_i\) = The Index value for the characteristic of the studied water quality.
- \(Z_i\) = The standardized variable value.

3. Calculating the IWQI as follow:

\[ IWQI = \frac{1}{N} \sum_{i=1}^{N} WQI_i \]  

Where
- IWQI = The index Water Quality Index for the characteristic.
- WQI = Irrigation Water Quality Index.

Table (2) explains water classes depending on IWQI value.

3. Statistical analysis:
The statistical analysis was conducted using SPSS version 26, PCA and CA for classification the studied spring waters depending on the studied variables or parameter.

Table 2. Irrigation water classification by [21]

| IWQI | Water use restriction       |
|------|----------------------------|
| 1    | Excellent IWQI or IWQI ≤ 1.96 |
| 2    | Good 1.96 < IWQI or IWQI ≤ 5.88 |
| 3    | Average 5.88 < IWQI or IWQI ≤ 9.80 |
| 4    | Poor WQI or IWQI > 9.80 |

3. Results and Discussion
3.1. Water classification:
Table (3) explains the range, mean and standard deviation (SD) for the studied spring waters in both wet and dry seasons at 22 locations in Erbil governorate.

The studies spring waters were classified according to Ayres and Westcot 1994 depending on EC, SAR, HCO3-, Cl- and pH as shown in table (4).

Depending on EC value the studies spring waters were classified into three classes, non-restricted, slight to moderate and sever restriction class which included (12,8,2) and (9,9,4) springs for wet and dry season respectively. It is appearing that the number of water classes at dry season shifted towards worse classes for example the number of spring waters having sever restriction of use increased from
2 water samples at wet season to 4 samples at dry season, this may be due to increase in temperature and decrease in precipitation at dry season similar results was recorded by [17]. Depending on the mentioned parameters the water samples were classified in both seasons in to (2 to 3) classes as shown in table (4). The variation in season caused conversion in water class depending on EC, SAR, HCO3- and Cl- while depending on pH the results at both seasons are similar. The water for (3) springs had acidic pH, due to high concentration of sulphate which may cause formation of weak H2SO4 that caused decrees in pH value. Depending on irrigation water quality index using all the studied parameters the spring waters were classified into two classes in both wet and dry seasons, the classes for (15 and 7) water samples were Excellent and good for irrigation respectively (Table,5). On the other hand depending on IWQI value depending on EC value as mentioned by [21] the studied spring waters were classified in three classes as shown in table (6), the water for (13, 5 and 4) springs had excellent, good and poor class in wet season, while the water of (12, 4 and 4) springs had excellent, good and poor class in dry season.

Table 3. Minimum, maximum, mean and standard deviation (SD) for the studied water variables in both wet and dry season [EC (dS m-1) main ions in mmolc L-1 and heavy metals in mg L-1]

| Variable | Wet season | Dry season |
|----------|------------|------------|
|         | Min. | Max. | Mean | S.D | Min. | Max. | Mean | S.D |
| EC      | 0.230 | 3.080 | 1.184 | 1.022 | 0.370 | 4.050 | 1.392 | 1.209 |
| pH      | 5.720 | 7.690 | 6.707 | 0.460 | 5.570 | 7.620 | 6.662 | 0.544 |
| Ca2+    | 0.640 | 20.640 | 4.887 | 6.553 | 0.400 | 31.600 | 6.066 | 10.890 |
| Mg2+    | 0.320 | 12.350 | 5.040 | 3.169 | 0.040 | 21.220 | 6.265 | 3.950 |
| Na+     | 0.030 | 12.700 | 1.788 | 3.152 | 0.040 | 9.040 | 1.529 | 2.520 |
| K+      | 0.010 | 0.860 | 0.125 | 0.010 | 0.010 | 0.290 | 0.064 | 0.075 |
| HCO3-   | 1.160 | 28.200 | 7.579 | 7.645 | 2.250 | 30.360 | 8.571 | 9.033 |
| Cl-     | 0.310 | 7.440 | 1.270 | 1.750 | 0.520 | 5.080 | 1.148 | 1.037 |
| SO4 2-  | 0.140 | 22.400 | 2.805 | 5.496 | 0.170 | 21.350 | 4.056 | 5.047 |
| NO3 -   | 0.000 | 0.540 | 0.185 | 0.166 | 0.030 | 0.430 | 0.133 | 0.124 |
| Fe      | 0.010 | 0.120 | 0.060 | 0.027 | 0.020 | 0.200 | 0.065 | 0.038 |
| Pb      | 0.000 | 0.010 | 0.002 | 0.004 | 0.000 | 0.010 | 0.002 | 0.004 |
| Mn      | 0.000 | 0.100 | 0.048 | 0.031 | 0.000 | 0.100 | 0.048 | 0.031 |
| Zn      | 0.030 | 0.530 | 0.230 | 0.129 | 0.030 | 0.530 | 0.233 | 0.126 |

Table 4. Water class depending on [1]

| Parameters | Water class | No. springs | Restriction of use | Wet season | Dry season |
|------------|-------------|-------------|--------------------|------------|------------|
|            | None        | 12          | 9                  |            |            |
| EC (dS m-1) | Slight to moderate | 8           | 9                  |            |            |
|            | Sever       | 2           | 4                  |            |            |
|            | None        | 20          | 21                 |            |            |
| SAR        | Slight to moderate | 2           | 1                  |            |            |
|            | Sever       | 0           | 0                  |            |            |
|            | None        | 1           | 0                  |            |            |
|            | Slight to moderate | 18          | 18                 |            |            |
| HCO3-      | Sever       | 3           | 4                  |            |            |
|            | None        | 20          | 21                 |            |            |
|            | Slight to moderate | 2           | 1                  |            |            |
| Cl-        | Sever       | 0           | 0                  |            |            |
|            | None        | 19          | 19                 |            |            |
| pH         | Slight to moderate | 0           | 0                  |            |            |
|            | Sever       | 3*          | 3*                 |            |            |

*Since the pH of them was acidic.
Table 5. Water classes depending on IWQI classification.

| Water class | No. of Springs | Wet season | No. of Springs | Dry season | IWQI value | No. of Springs | Dry season | IWQI value |
|-------------|----------------|------------|----------------|------------|------------|----------------|------------|------------|
| Excellent   | 15             | 0.21 – 1.07| 15             | 0.17– 1.06|
| Good        | 7              | 1.97-3.21  | 7              | 1.97-4.82  |

Table 6. IWQI classification depending on (EC dS m-1) values

| Water class | No. Springs | Wet season | No. of Springs | Dry season | IWQI value | No. of Springs | Dry season | IWQI value |
|-------------|-------------|------------|----------------|------------|------------|----------------|------------|------------|
| Excellent   | 13          | 0.23-0.71  | 12             | 0.54-0.79  |
| Good        | 5           | 0.86-1.5   | 4              | 0.86-1.60  |
| Poor        | 4           | 2.86-3.08  | 4              | 2.94-4.05  |

The results of Agglomerative hierarchical clustering (AHC) or cluster analysis (CA) indicated clustering the studies spring waters into 3 clusters as shown in table (7) the clustering or grouping the waters into three groups in both seasons depending on the studied water chemical properties similar waters in chemical properties can be grouping in the same group depending on the similarity in cluster analysis, also depending on the studied water characters or variables the same results were obtained in classification of the water samples depending on [1].

Table 7. Clusters for the studies spring waters at wet and dry season

| Water clusters | Spring number in Wet season | Dry season |
|----------------|-----------------------------|------------|
| C1             | 1, 5, 6, 7, 8, 9, 10, 11, 12,13, 14, 15,16,17,19,20,21 | 1, 5, 6, 7, 8, 9, 10, 11, 12,13, 14, 15,16,17,19,20,21 |
| C2             | 2, 3, 4                     | 2, 3, 4    |
| C3             | 18, 22                      | 18, 22     |

Figure (1 and 2) show the dendrogram of similarity for the studied spring waters in wet and dry season

Figure 1. The dendrogram for the studied water samples at wet season
respectively. The dendrogram classified the studied water samples into three groups or clusters or classes the space is exceeded between clusters, each cluster contains water samples having similarity or dissimilarity in the studied chemical properties of the water samples or the studied variables.

![Dendrogram](image1.png)

**Figure 2.** The dendrogram for the studied water samples at dry season

![Profile plot](image2.png)

**Figure 3.** Profile plot for the obtained water clusters depending on the maximum values of the studied variables in wet season with the same units used in table (3).
Figure 4. Profile plot for the obtained water clusters depending on the maximum values of the studied variables in dry season with the same units used in table (3).

The principal component analysis also regards as a tool or method for classification of the water samples into different groups and the factors which caused the variation among the water samples. The factor which had eigenvalue ≥ 1 is responsible for variation in water properties, the factor which had the highest value causes the highest variation in water quality or chemical properties as shown in (8). The loading factor values for the parameters ≥ than selection criterion (SC) value of factor means that the factor affected significantly on this parameter. It is appear from the mentioned table that the (F1 and F2) caused 34.2 and 28.66% variation in the studied water parameters, this two factors may be geological formation of the studied location, amount of rainfall or climatic factor, the other two factors had less effect of the water quality had significant effect on Pb and Zn plus NO3- for both dry and wet season respectively. These results are similar with those recorded by [18].

Figure (5) explains the biplot for grouping the studied spring waters in wet season, which group them into three groups, except spring number 22 which located between group 2 and 3 (Triangle and the small circle). The angles between vectors refers to the correlation coefficient between them if the angle between two parameters is more than 90 it means there is negative correlation between them , while if the angle =90 degree it means zero correlation coefficient value, decrease in the angle means increase in correlation coefficient if the angle approached to zero the correlation coefficient value approach to 1 or positive perfect correlation , while if the angle between them approached to 180 degree the correlation coefficient approach to (-1) or negative perfect correlation coefficient.

The figure (5 and 6) are referring to biplot grouping of the the studied water for (22) springs into three groups in wet and dry season respectively, but their locations are differing from wet season in comparing with dry season. This may be due to the variation in chemical composition of the studied water samples in the studied two seasons of sampling due to the difference in climatical condition between the mentioned two season of sampling. These results agree with those recorded by [16]; [17].
Table 8. Loading factors, eigenvalues and SC for the studied water samples*

| Parameters | F1  | F2  | F3  | F4  | F1  | F2  | F3  | F4  |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|
| EC         | 0.84| -0.54| -0.02| 0.03| 0.49| 0.87| 0.02| 0.01|
| pH         | 0.03| 0.88 | -0.01| 0.18| 0.28| 0.85| 0.17| -0.10|
| Ca2+       | 0.58| -0.75| 0.05 | 0.20| 0.04| 0.98| 0.11| -0.06|
| Mg2+       | 0.67| -0.66| -0.13| -0.14| 0.82| -0.04| -0.39| 0.14|
| Na+        | 0.80| 0.45 | -0.03| -0.14| 0.89| -0.05| 0.21| 0.06|
| K+         | 0.57| 0.42 | -0.09| -0.43| 0.78| -0.03| 0.37| 0.26|
| HCO3-      | 0.47| -0.76| -0.14| -0.38| 0.20| 0.92| 0.01| 0.27|
| Cl-        | 0.69| 0.54 | -0.24| -0.07| 0.85| -0.18| 0.03| -0.03|
| SO4 2-     | 0.67| -0.12| 0.22 | 0.61| 0.61| 0.47| 0.03| -0.46|
| NO3-       | 0.26| 0.30 | 0.77 | -0.03| 0.44| -0.20| -0.65| -0.40|
| Fe         | 0.78| 0.28 | 0.33 | 0.04| 0.73| -0.03| -0.30| 0.03|
| Pb         | 0.22| 0.16 | -0.59| 0.61| 0.24| -0.11| 0.77| -0.42|
| Mn         | 0.61| 0.47 | -0.01| 0.06| 0.73| -0.19| 0.02| -0.10|
| Zn         | 0.27| 0.47 | -0.37| -0.27| 0.45| -0.36| 0.10| 0.54|
| SC value   | 0.23| 0.25 | 0.43 | 0.45| 0.22| 0.26| 0.41| 0.50|
| Eigenvalue | 4.76| 4.01 | 1.34 | 1.26| 5.02| 3.76| 1.48| 1.04|
| Variability (%) | 34.02| 28.66| 9.54 | 9.01| 35.86| 26.82| 10.60| 7.40|
| Cumulative % | 34.02| 62.68| 72.23| 81.24| 35.86| 62.68| 73.28| 80.68|

*Bold values means the variable affected significantly by factors.

Figure 5. The biplot for the studied spring waters in wet season
Figure 6. The biplot for the studied spring waters in dry season.

4. Conclusion
The results for studying the water quality for 22 springs in north east of Erbil governorate indicated to their grouping or classification into three classes depending on four methods of classification. In general, most of the studied spring waters were suitable for irrigation purpose. The principal component analysis and cluster analysis are also two suitable tools or methods for identification water quality for irrigation.

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