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Comparison Between Groundwater Quality at North East and South West of Erbil Governorate for Irrigation Using Some Global Systems and Principal Component Analysis

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Abstract: **This investigation was conducted during June ,2019 to November ,2019 for classification of water of (54) wells in Erbil province 26 of them in north and north east of Erbil and the other half at south west of Erbil. The studied waters were classified for irrigation purpose depending on some global systems or classification and Principal component analysis was done for the calculated parameters used in classification.. Depending on USDA classification(1954) the water of the water of (20 and 6) locations or wells having C2S1 and C3S1 Class respectively .While for the south east Erbil wells the water classes were C1S1, C2S1 , C3S1 and C4S1 for (1,5,17, and 3) wells it means the water quality in south west of Erbil west is bad in comparing with the water for wells in north and north east of Erbil. Depending Ayres and Westcot (1985) and Doneen classification the water wells in north and north east of Erbil had better water classes in comparing with the groundwater in south west of Erbil.,. A scree plot for eigenvalues recorded in this investigation showed the pronounced change of slope after the third eigenvalue. Eigenvalue close or greater than one (unity) were three factors for north and north east of Erbil and two factors for water of south west of Erbil due to its higher EC value.**

Keywords: **Groundwater; water classification; Principal component analysis; Erbil.**

*** Part of MSc. thesis for the 1st author.**

I. Introduction

Groundwater regards as a source of water resources in Iraq especially in Iraqi Kurdistan region since the irrigation projects are not existing in this part of Iraq except very small irrigation projects in some villages [1]. Groundwater has a significant role in agricultural uses and drinking purpose in rural areas [2]. The groundwater quality is simply the result of the geology and hydrology of the area, types and chemical composition of rocks, weathering in the source area, and final mineral composition of the sediments are the main factors controlling the quality and chemical composition of the studied water [2]. Groundwater quality is varied from location to other depending on geological formation of catchment area, chemical composition of aquifer, environmental condition …etc. [3,4]. The large basin of ground water is existing in Erbil governorate in comparing with the area of groundwater basin in other governorates which equal to more than (5000 km^2) and the number of drilled wells is about (10000) wells [1]. Research's [5] and [6] indicated that the advancement in technology caused an increase in drilling wells and use of groundwater reached too deep of aquifers to obtain large amount of water, the quality was classified depending on the main chemical properties for irrigation as follow:

1. Classification of water for irrigation uses:

The most important global systems for irrigation water classification was summarized as follow:

1.1. Richards or USDA classification (1954):

This classification depending on electrical conductivity and sodium adsorption ratio (EC and SAR), separately classified into four classes as shown in Table 1, and classified into 16 classes when it depending on both EC and SAR Table 2.

Table 1.Richards classification for irrigation water (1954)

Water class	**Electrical conductivity µmohs cm -1 at 25 ˚C**	**Water class**	**SAR**	**Water class**
C1 = low-salinity	0 < EC ≤ 250	S1	S1 < 10	C1 = low-salinity
C2 = medium-salinity	250 <EC ≤ 750	S2	10 < S2 ≤ 18	C2 = medium-salinity
C3 = high-salinity	750 < EC ≤ 2250	S3	18 < S3 ≤ 26	C3 = high-salinity
C4 = very high-salinity	2250 < EC ≤ 5000	S4	S4 > 26	C4 = very high-salinity

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$ .... When: SAR = Sodium adsorption ratio

Na = Sodium concentration, Ca = Calcium concentration, Mg = Magnesium concentration (mmol L^{-1})

1.2. Doneen classification (1954):

Depending on Doneen [7] the irrigation water were classified as shown in Table 2.

Table 2. Doneen classification of water.

Water class	**Salinity potential (SP) =$Cl^{-}+1/2\ SO_4^{2-}$ ($mmol_c\ L^{1}$)**		
	Permeability		
	High	Moderate	Low
Good	< 7	< 5	< 3
Moderate	7 – 15	5 - 10	3 – 5
Bad	> 15	> 10	> 5

1.3. Wilcox classification (1955):

This classification of water depending on residual sodium carbonate (RSC), which classified into three classes Table 3.

Table 3. Water classification depending on RSC.

Water class	**RSC=$({CO_3}^{2-} + {HCO_3}^{-}) - (Ca^{2+} + Mg^{2+})$**
	RSC ($mmol_c^{-1}$)
1- probably safe	<1.25
2- Marginal	1.25-2.5
3- Unsuitable	>2.5

1.4. Ayers and Westcot classification (1985).

Ayers and Westcot [8] depended on EC (dS.m^{-1}), SAR of the soil, in classification of the irrigation water into three classes Table 4.

Table 4. Ayers and Westcot irrigation water classification (1985).

1.5.

Potential irrigation problem	Unit	Degree of restriction use		
		None	Slight to moderate	Severe
Salinity	dS m^{-1}	< 0.7	0.7-3.0	> 3.0
EC_{iw} at 25 ^{o}C				
Infiltration	(mmol$_c$ l^{-1})$^{1/2}$	> 0.7	0.7-0.2	< 0.2
Sodium toxicity (SAR) Surface irrigation		< 3	3-9	> 9
pH	Normal Range 6.5-8.4			

1.5. Don classification (1995):

This classification based on EC, SAR, Na % and pH, the water classification classified into five classes which explained in Table 5.

Table 5. water classification based on TDS, EC, SAR, Na% and pH.

Water quality	EC (dS m^{-1}	Na%	SAR	pH
Excellent	<0.25	20	3	6.5
Good	0.25 – 0.75	20 – 40	3 – 5	6.5 – 6.8
Permissible	0.75 – 2.0	40 – 60	5 – 10	6.8 – 7.0
Doubtful	2.0 – 3.0	60 – 80	10 – 15	7.0 – 8.0
Unsuitable	>3.0	>80	>15	>8.0

The groundwater quality for a limited area was conducted by numerous workers such as [3] and [9-12]. Since none of the studies included wide area of Erbil governorate and none of them depended on principal component analysis for comparing between water qualities for this reason this study was done to:

1- Classification the groundwater in north and south Erbil governorate for irrigation.
2- Using Principal component analysis for water evaluation.

II. Materials and Methods:

2.1. Study area:

The study was conducted during the dry season of 2019; the samples were taken from 22 of June to 2 of July 2019 from 52 locations in agricultural lands of Erbil governorate Iraqi Kurdistan region which including (North and north east of Erbil (26) and south west of Erbil(26) samples. The GPS reading for the studied locations were recorded in table (2-1) and 2-2).

2.2. Water sampling:

Water samples were collected from (52) wells as mentioned above the depth of the wells was between (150 – 300) m, and the water were taken by using plastic bottle of 330 ml. The water samples were kept in refrigerator at (4 ^{o}C) and send it to the laboratory for analysis.

2.3. Water chemical analysis:

Various chemical analyses were analyzed as follow:

1. Electrical conductivity (EC), Potential Hydrogen (pH) and temperature of the water samples were recorded at the site by using EC, pH and temperature meter Model (HI 9814) (APHA,2009)..
2. Cations and trace element of water sample were analyzed in the laboratory by using inductive coupled plasma optical emission spectrometer 2100DV (ICPOES 2100 DV), the cations were (Ca^{2+}, K^{+}, Na^{+} and Mg^{2+}).
3. system (ICS 1500), (Dionex ICS 1500), which were (.SO_4^{2-}, Cl^{-}, SO_4^{2-} and HCO_3^{-}).

III. Statistical Analysis:

The statistical analysis was conducted using SPSS program version 22 and XLSTAT,2016.

Table 6. GPS reading of the south west of Erbil.

NO.	Locations	latitude	longitude
1	Shamshula (1)	37˚77'96.00 "	44˚08'37.20 "
2	Shamshula (2)	36˚58'98.00 "	44˚01'61.60 "
3	Shamshula (3)	36˚94'87.00 "	44˚11'58.60 "
4	Shamshula (4)	36˚88'31.00 "	44˚04'58.20 "
5	Gwer (1)	37˚04'04.00 "	44˚06'86.20 "
6	Gwer (2)	37˚38'14.00 "	44˚18'04.40 "
7	Gwer (3)	37˚76'06.00 "	44˚11'43.60 "
8	Abo Sheta (1)	37˚86'09.00 "	44˚03'40.70 "
9	Abo Sheta (2)	37˚86'41.00 "	44˚03'41.30 "
10	Abo Sheta (3)	37˚86'87.00 "	44˚03'44.70 "
11	Zaga	37˚75'70.00 "	43˚97'86.80 "
12	Qadria	37˚94'67.00 "	44˚38'30.20 "
13	Hawera	37˚46'50.00 "	44˚39'07.20 "
14	Gainj	37˚20'88.00 "	44˚19'61.20 "
15	Klaw Rash (1)	37˚87'37.00 "	44˚01'96.00 "
16	Klaw Rash (2)	37˚86'47.00 "	44˚01'78.60 "
17	Klaw Rash (3)	37˚77'02.00 "	44˚01'74.40 "
18	Gamesh Tapa (1)	37˚84'66.00 "	44˚03'96.40 "
19	Gamesh Tapa (2)	37˚82'77.00 "	44˚03'77.90 "
20	Gamesh Tapa (3)	37˚83'78.00 "	44˚03'65.00 "
21	Kapran (1)	37˚79'65.00 "	44˚03'37.90 "
22	Kapran (2)	37˚94'48.00 "	44˚03'79.50 "
23	Kapran (3)	37˚88'34.00 "	44˚03'90.60 "
24	Alyawa (1)	36˚44'24.00 "	44˚06'13.40 "
25	Alyawa (2)	36˚50'77.00 "	44˚06'41.00 "
26	Alyawa (3)	36˚44'55.00 "	44˚06'11.80 "

Table 7. GPS reading of North and north east of Erbil.

NO.	Locations	latitude	longitude
1	Bnawe	36°28'04.00 "	44°22'74.30 "
2	Gomspan	36°27'30.00 "	44°13'01.70 "
3	Heran	36°71'92.00 "	44°17'51.00 "
4	Solawk	36°29'99.00 "	44°14'11.20 "
5	Sewaka	36°33'63.00 "	44°11'77.90 "
6	Sheraswar	36°46'53.00 "	44°22'58.80 "
7	Hajran	36°41'03.00 "	44°09'62.80 "
8	Aghulan	36°84'42.00 "	44°20'00.60 "
9	Hanara	36°29'02.00 "	44°42'54.80 "
10	Qalasnj	36°96'76.00 "	44°24'00.20 "
11	Mala Omer	36°19'63.00 "	44°17'46.50 "
12	Kalakeen	36°25'66.00 "	44°40'98.90 "
13	Shawes	36°25'19.00 "	44°40'92.50 "
14	Tawska	36°68'00.00 "	44°26'93.70 "
15	Khoran	36°22'48.00 "	44°21'04.00 "
16	Kore	36°31'99.00 "	44°28'79.00 "
17	Shaqlawa (1)	36°39'80.00 "	44°33'58.00 "
18	Shaqlawa (2)	36°39'85.00 "	44°43'29.10 "
19	Shaqlawa (Semon 3)	36°40'18.00 "	44°43'26.80 "
20	Sebardan	36°15'92.00 "	44°12'03.90 "
21	Sharabot	36°24'36.00 "	04°42'04.80 "
22	Mam Choghan	36°22'21.00 "	44°21'20.00 "
23	Senan	36°17'14.00 "	44°56'01.00 "
24	Krosh	36°17'70.00 "	44°56'11.00 "
25	Smaquli	36°17'07.00 "	04°45'84.80 "
26	Awgrd	36°20'90.00 "	04°44'94.80 "

The chemical variables of properties of the studied water samples and scientific parameters were recorded in table (8,9,10 and 11) and the parameters were calculated depending on the following equations:

Soluble sodium percentage (SSP).

$$\text{SSP} = \frac{Na^{+}\ (meql^{-1})}{Total\ soluble\ cation\ concentration\ \ (meql^{-1})}\ \textbf{X 100.}\ \ldots\ldots\ldots\ldots\ \textbf{(1)}$$

Sodium adsorption ratio (SAR).

$$\textbf{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Ion concentrations must be expressed in $mmol_c\ L^{-1}$(meq L^{-1}) to calculate SAR using above equation.

Adjusted sodium adsorption ratio (Adj. SAR).

$$\textbf{Adj.SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}\ \{1+(8.4-pHc)\} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where:
Na^+, Ca^{2+}, Mg^{2+} = Sodium, calcium, magnesium concentration in meq L^{-1} **pHc** = (pK_2 - pKc) + p (Ca^{2+} + Mg^{2+}) + p(ALK)
(pK_2 - pKc) = The tabulated value for sum of concentrations of (Ca^{2+} + Mg^{2+} + Na^+) meq L^{-1}.
pKc = The solubility product of $CaCO_3$.
pK_2 = Second dissociation constant of calcium bicarbonate.
p(Ca^{2+} + Mg^{2+}) = the tabulated value for sum of the concentration of (Ca^{2+} + Mg^{2+}) meq L^{-1}
p(ALK) = the tabulated value for sum of the concentration of (CO_3^{2-} + HCO_3^-) meq L^{-1}

Adjusted sodium adsorption ratio (Adj.RNa).

$$\textbf{Adj. RNa} = \frac{Na^{+}}{\sqrt{\frac{Ca_x^{2+}+Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where;
Na^+ = Sodium concentration in meq L^{-1}.
Mg^{2+} = Magnesium concentration in meq L^{-1}.
Ca_x^{2+} = A modified calcium value taken from table adapted from which depends on EC and $\frac{HCO_3^-}{Ca^{2+}}$ ratio.

Salinity potential:
Salinity potential (SP) =Cl^- +1/2 SO_4^{2-}(mmolc L^{-1}) or meq L^{-1}

Table 8. Some chemical properties of the studied groundwater in North and East of Erbil province.

No.	Location	EC	pH	pHc	Ca^{2+}	K^+	Na^+	Mg^{2+}	SO_4^{2-}	HCO^3_-	Cl^-
1	Bnawe	0.66	7.83	7.45	3.90	0.02	0.27	2.44	2.00	3.40	1.23
2	Gomspan	0.67	7.87	7.30	3.00	0.02	0.25	3.90	3.42	2.39	1.25
3	Heran	0.27	8.01	8.05	1.14	0.01	0.06	1.70	1.40	1.00	0.49
4	Solawk	0.53	7.95	7.50	3.01	0.01	0.17	2.09	2.02	1.97	1.19
5	Sewaka	1.18	7.52	6.80	6.71	0.01	0.36	5.09	4.12	5.39	2.55
6	Sheraswar	0.37	7.87	7.60	2.30	0.01	0.23	1.34	1.45	2.00	0.41
7	Hajran	0.69	8.01	7.40	4.12	0.02	0.29	3.00	2.47	3.50	1.67
8	Aghulan	1.23	7.84	6.75	6.61	0.01	1.98	4.23	4.32	6.34	2.20

9	Hanara	0.85	7.96	7.10	4.22	0.01	1.35	3.55	3.24	4.33	1.40
10	Qlasnj	0.72	8.07	7.60	2.55	0.02	2.60	1.98	3.56	2.00	1.50
11	Mala Omer	0.78	7.85	7.20	3.34	0.01	2.33	2.33	2.90	3.97	1.09
12	Kalakeen	0.37	7.84	7.70	2.00	0.01	0.48	1.34	1.40	2.00	0.59
13	Shawes	0.40	7.96	7.60	2.14	0.01	0.17	1.82	2.01	1.69	0.40
14	Tawska	0.30	8.08	7.80	1.78	0.01	0.44	1.00	1.09	1.55	0.46
15	Khoran	0.33	8.02	8.30	1.90	0.03	0.74	1.02	1.43	1.59	0.50
16	Kore	0.50	7.93	7.50	2.15	0.01	1.20	2.10	1.90	2.30	1.20
17	Shaqlawa (1)	0.60	7.95	7.80	2.30	0.02	2.20	1.80	2.40	2.56	1.40
18	Shaqlawa (2)	0.63	7.51	7.50	4.22	0.01	0.30	2.02	2.74	2.18	1.71
19	Shaqlawa (3)	0.79	7.96	7.10	4.00	0.01	0.58	3.67	3.10	4.38	0.72
20	Sebardan	0.34	7.81	7.80	2.35	0.01	0.12	1.01	1.24	1.50	0.72
21	Sharabot	0.53	7.95	7.50	2.33	0.02	0.29	3	2.13	2.07	1.41
22	Mam Choghan	0.40	8.11	7.60	2.10	0.01	0.20	1.89	1.67	2.01	0.70
23	Senan	1.59	8.36	6.60	7.50	0.17	3.55	5.2	4.9	8.24	3.20
24	Krosh	0.81	7.99	7.15	4.30	0.04	0.58	3.22	2.89	3.2	2.00
25	Smaquli	0.55	7.85	7.80	1.95	0.02	1.00	2.9	2.56	2.12	1.00
26	Awgrd	0.58	7.96	7.60	2.35	0.01	1.34	2.11	2.22	2.3	1.11
$LSD_{.01}$		0.21	0.43	0.40	1.50	0.01	0.44	1.02	1.09	1.43	0.23

Table 9. Shows some studied groundwater parameter in North and East of Erbil province.

No.	Location	RSC	SAR	Adj.SAR	Adj RNa	SP	SSP
1	Bnawe	-2.94	0.11	0.21	0.15	2.23	4.07
2	Gomspan	-4.51	0.10	0.20	0.12	2.96	3.49
3	Heran	-1.84	0.04	0.05	0.04	1.19	2.08
4	Solawk	-3.13	0.08	0.14	0.09	2.2	3.22
5	Sewaka	-6.41	0.1	0.27	0.16	4.61	2.96
6	Sheraswar	-1.64	0.12	0.22	0.14	1.14	5.93
7	Hajran	-3.62	0.11	0.22	0.15	2.91	3.9
8	Aghulan	-4.5	0.6	1.59	0.94	4.36	15.43
9	Hanara	-3.44	0.48	1.11	0.69	3.02	14.79
10	Qlasnj	-2.53	1.22	2.2	1.41	3.28	36.36
11	Mala Omer	-1.7	0.98	2.15	1.34	2.54	29.09
12	Kalakeen	-1.34	0.26	0.44	0.3	1.29	12.44
13	Shawes	-2.27	0.09	0.15	0.09	1.41	4.11
14	Tawska	-1.23	0.26	0.42	0.28	1.01	13.62
15	Khoran	-1.33	0.43	0.48	0.43	1.22	20.05
16	Kore	-1.95	0.58	1.11	0.69	2.15	21.98
17	Shaqlawa (1)	-1.54	1.09	1.74	1.33	2.6	34.81
18	Shaqlawa (2)	-4.06	0.12	0.23	0.15	3.08	4.58
19	Shaqlawa (3)	-3.29	0.21	0.48	0.3	2.27	7.02

20	Sebardan	-1.86	0.07	0.1	0.07	1.34	3.44
21	Sharabot	-3.26	0.13	0.24	0.15	2.48	5.14
22	Mam Choghan	-1.98	0.1	0.18	0.12	1.54	4.76
23	Senan	-4.46	1	2.79	1.62	5.65	21.62
24	Krosh	-4.32	0.21	0.48	0.29	3.45	7.13
25	Smaquli	-2.73	0.45	0.73	0.55	2.28	17.04
26	Awgrd	-2.16	0.63	1.14	0.77	2.22	23.06

Table 10. Some chemical properties of the studied groundwater in south east of Erbil province.

No.	Location	EC	pH	pHc	Ca^{2+}	K^{+}	Na^{+}	Mg^{2+}	SO_4^{2-}	HCO_3^{-}	Cl^{-}
1	Shamshula (1)	1.35	7.84	6.7	6.38	0.02	0.48	7.12	6.3	5.75	2.12
2	Shamshula (2)	0.33	7.84	7.65	2	0.01	0.22	1.5	1.45	1.37	0.8
3	Shamshula (3)	2.1	7.82	6.6	11.6	0.01	7.45	2.89	11	7.71	3.2
4	Shamshula (4)	0.33	7.83	7.8	2.01	0.01	0.23	1.42	1.47	1.34	0.82
5	Gwer (1)	0.33	7.9	7.8	2.12	0.01	0.22	1.23	1.43	1.32	0.84
6	Gwer (2)	1.35	7.91	6.8	8.11	0.01	1.56	5.45	6	5	4.12
7	Gwer (3)	1.39	7.84	6.9	6.77	0.02	5.17	2.99	6	5.02	2.89
8	Abo Sheta (1)	1	7.8	7.1	4.8	0.01	2.21	3.89	5.9	4	1.05
9	Abo Sheta (2)	0.92	7.91	7.1	3.15	0.01	1.21	5.1	4.4	3.72	1.2
10	Abo Sheta (3)	0.85	8.01	7	2.93	0.01	1.22	4.82	2.42	5.33	1.2
11	Zaga	0.21	7.86	8.2	1	0.01	0.28	0.99	1.11	0.81	0.38
12	Qadria	0.31	7.84	7.4	1.5	0.01	0.68	1.24	1.4	1.6	0.44
13	Hawera	1.79	7.85	6.6	6.98	0.01	2.6	9.78	8.8	7.72	3.21
14	Gainj	0.66	8.01	7.5	3.2	0.02	1.44	2.17	3	2.15	1.67
15	Klaw Rash (1)	1.16	7.89	7.1	4.61	0.01	2.2	4.93	3.99	6	1.61
16	Klaw Rash (2)	1.23	7.87	7.1	5.34	0.01	4.39	2.8	7	4.3	1.3
17	Klaw Rash (3)	1.05	7.86	7.1	3.45	0.02	3.23	4	5.78	3.52	1.23
18	Gamesh Tapa (1)	0.98	7.95	7.2	4.35	0.02	2.34	3.45	5.6	3.23	1.2
19	Gamesh Tapa (2)	0.84	8.12	7.5	3.5	0.02	2.23	3	4.2	3.5	0.94
20	Gamesh Tapa (3)	0.96	8.09	7.4	3.32	0.02	3.23	3.21	5.2	2.84	1.7
21	Kapran (1)	1.23	7.78	6.9	4.09	0.02	3.35	5.65	6	4.91	2
22	Kapran (2)	1.13	8.05	7.1	4.45	0.02	3.23	3.75	5.73	4	1.67
23	Kapran (3)	0.89	8.1	7.3	3.9	0.02	2.22	3	5	3	1.09
24	Alyawa (1)	3.84	7.5	6	21.9	0.02	7.9	8.99	17.98	14.2	7.2
25	Alyawa (2)	6	7.49	5.8	38.19	0.03	13.9	9.9	30.1	23	10.12
26	Alyawa (3)	2.35	7.95	7.8	12.2	0.01	0.5	11	6.4	11.43	5.96
$LSD_{0.01}$		024	0.31	0.22	1.05	0.01	2.34	2.90	3.22	3.80	2.67

Table 11. Shows some studied groundwater parameter in south west Erbil province.

No.	Location	RSC	SAR	Adj.SAR	Adj RNa	SP	SSP
1	Shamshula $_1$	-7.75	0.13	0.35	0.2	5.27	3.43
2	Shamshula $_2$	-2.13	0.12	0.2	0.12	1.53	5.83

3	Shamshula $_3$	-6.78	1.96	5.48	3.52	8.7	33.94
4	Shamshula $_4$	-2.09	0.12	0.2	0.13	1.56	6.26
5	Gwer $_1$	-2.03	0.12	0.19	0.12	1.56	6.05
6	Gwer $_2$	-8.56	0.42	1.1	0.65	7.12	10.31
7	Gwer $_3$	-4.74	1.65	4.14	2.55	5.89	34.58
8	Abo Sheta $_1$	-4.69	0.75	1.72	1.07	4	20.26
9	Abo Sheta $_2$	-4.53	0.42	0.97	0.57	3.4	12.78
10	Abo Sheta $_3$	-2.42	0.44	1.05	0.63	2.41	13.59
11	Zaga	-1.18	0.2	0.24	0.18	0.94	12.28
12	Qadria	-1.14	0.41	0.82	0.43	1.14	19.83
13	Hawera	-9.04	0.64	1.78	0.98	7.61	13.42
14	Gainj	-3.22	0.62	1.18	0.73	3.17	21.08
15	Klaw Rash $_1$	-1.04	0.18	0.41	0.14	0.91	12.43
16	Klaw Rash $_2$	-3.84	1.54	3.54	2.27	4.8	35.01
17	Klaw Rash $_3$	-3.93	1.18	2.72	1.62	4.12	30.19
18	Gamesh Tapa $_1$	-4.57	0.84	1.84	1.14	4	23.03
19	Gamesh Tapa $_2$	-3	0.87	1.66	1.18	3.04	25.49
20	Gamesh Tapa $_3$	-3.69	1.26	2.53	1.63	4.3	33.03
21	Kapran $_1$	-4.83	1.07	2.68	1.56	5	25.55
22	Kapran $_2$	-4.2	1.13	2.59	1.56	4.54	28.21
23	Kapran $_3$	-3.9	0.85	1.77	1.13	3.59	24.29
24	Alyawa $_1$	-16.69	1.42	4.83	2.82	16.19	20.36
25	Alyawa $_2$	-25.09	2	7.22	4.75	25.17	22.41
26	Alyawa $_3$	-1.77	0.28	0.45	0.28	1.66	13.48

IV. Results and Discussion:

The minimum, maximum, mean and standard deviation for the studied variables of the studied water samples at both locations in Erbil governorate were recorded in Table 12 which prepared from Tables 8,9,10 and 11) which were depended in both classification of the studied water for irrigation and principal component analysis(PCA) .

Table 12. Shows the values of the studied variables at two locations .

Variables		North and north east of Erbil				South and south west of Erbil			
EC (dS m^{-1})		Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
pH		0.27	1.59	0.64	0.31	0.21	6.00	1.33	1.22
pHc		7.51	8.36	7.93	0.17	7.49	8.12	7.88	0.15
Ca^{2+}	mmolc L-1	6.60	8.30	7.47	0.39	5.80	8.20	7.13	0.54
K^{+}		1.14	7.50	3.24	1.00	6.61	39.19	7.77	4.29
Na^{+}		0.01	0.17	0.02	0.01	0.03	0.02	0.01	0.01
Mg^{2+}		0.06	3.55	0.89	0.93	0.22	13.90	2.83	3.04
SO_4^{2-}		1.00	5.20	2.53	1.18	0.99	11.00	4.40	2.85
HCO^{3}_{-}		1.09	4.90	2.48	1.00	1.11	30.10	6.29	5.99
Cl^{-}		1.00	8.24	2.92	1.68	0.81	23.00	5.26	4.74
SP		0.40	3.20	1.23	0.70	0.38	10.12	2.31	2.28
RSC		-6.41	-1.23	-2.85	1.30	-25.09	-1.04	-5.26	5.21
Ca2+		1.01	5.65	2.48	1.15	0.12	2.00	0.79	0.58
SAR		0.04	1.22	0.37	0.36	0.19	7.22	1.99	1.81

Adj.SAR	0.05	2.79	0.73	0.76	0.12	4.75	1.23	1.16
Adj RNa	0.04	1.62	0.48	0.48	0.91	25.17	5.06	5.20
SSP%	2.08	36.36	12.39	10.32	3.43	35.01	19.50	9.61

The statistical analysis indicated to significant difference at level of significant 0.01 between the chemical properties of the studied water samples for the studied wells of north and south Erbil (Table 8 and 10). Similar results were obtained by [11].

3.1. Water classification for irrigation:

The studied water was classified according to some global classification depending on Table (8 and 10) for north and north east of Erbil and depending on Table (9 and 11) for south west of Erbil as follow:

3.1.1. Recharded classification (1954):

The studied water according to this classification were classified as shown from table below. It is appearing that the water of (20 and 6) locations or wells having C_2S_1 and C_3S_1 Class respectively. It means the water class are differing depending on EC value, while they were similar in their class depending on SAR value, since the SAR value of the water in Kurdistan region is low due to high concentration of calcium and magnesium and low concentration of sodium as shown from (3.2) . This result agrees with those recorded by [3].While for the south east Erbil wells the water classes were C1S1, C2S1 , C3S1 and C4S1 for (1,5,17, and 3) wells it means the water quality in south west of Erbil west is bad in comparing with the water for wells in north and north east of Erbil .this may be due to the differing in geological formation of the studied two locations and the existing of upper Fars formation in south west of Erbil and Bakhtyari formation in north and north east of Erbil which caused increase in electrical conductivity and soluble salts in south west of Erbil in comparing with north and north east of Erbil (table,2.3 and 2.5).Similar results were obtained by [3].

3.1.2. Classification of Wilcox (1954):

Depending on Wilcox (1954) the water of all the studied wells for both (north and north east and South west) of Erbil having safe class since the residual sodium carbonate (RSC) below 1.25 mmolc L^{-1} or having negative values Table 13. This may be due to high concentration of calcium and magnesium in the studied water sample in comparing with the concentration of carbonate and bicarbonate .It is appear from Table 13 that the negative values for RSC were higher in south west of Erbil in comparing with its value at north and north east of Erbil (Table 13) due to the higher concentration of calcium ,magnesium , in south west of Erbil. These results agree with [11].

3.1.3. Ayers and Westcot (1985) classification:

Depending on some parameters the studied waters were classified according to Ayers and Westcot (1985) as shown from Table 13 In general, the quality of water in north and north east Erbil is better than the studied waters in south west of Erbil. This may be due to differing in the geological formation of the studied locations.

Table 13. Explains water classes according to Ayers and Westcot (1984).

Water Parameters		Degree of restriction for use					
		North and north east of Erbil			South west of Erbil		
		None	Slight -moderate	Sever	None	Slight - moderate	Sever
EC (dSm^{-1})		0	26	0	1	23	2
pH		26	0	0	26	0	0
SAR		26	0	0	26	0	0
Adj. SAR		26	0	0	21	5	0
HCO_3^-	$mmol_c$ L^{-1}	26	0	0	2	22	2
Cl-		26	0	0	22	3	1

3.2. Factor analysis:

In principal component analysis (PCA) analysis the number of components is equal to the number of variables. The eigenvalues was depended to determine the number of (PC) that can be retained for further study. A scree plot for eigenvalues recorded in this investigation showed the pronounced change of slope after the third and second eigenvalues (Table 14 ,Figure,1and 2) for north and south west Erbil respectively. Eigenvalue close or greater than one (unity) which explained (59.58,26.47 and 7.43) and (71.50 and 15.2) % of the total variation respectively for both locations respectively (Table 14). it means in the north and north east of Erbil three factors had significant loading or influence(Table14) while in south east two factors (F1 and F2) had significant effect on water quality due to higher EC values in south west of Erbil. The comparison between these two factors (F1 and F2) is necessary. It is appear from eigen values and variability% that the F1 is caused 59.58 and 71.50 % in water properties in (north and north east) and (south west) of Erbil respectively due to higher EC and ionic concentration in south east of Erbil in comparing with north and north east of Erbil. information contained in the original database and Table 14).The cumulative variation of these two factors was(80.05 and 85.6%) for both locations respectively ,while the third factor (F3) also significant in north and north east location which caused increase in cumulative 5 variability to93.48%. the variation effect of other factors can be neglect (F3 to F16) and (F4 to F16) for both locations respectively . Since the number of samples were26 samples per location with the degrees of freedom (df) =24 for this reason the correlation coefficient values equal or more than 0.47 is significant and contribute in factors or had significant effect on factors (table,3.3) The locations of the studied parameters or vectors in Figure (3 and 4) depends on positive or negative correlation between parameters and the factors in Table 14. The parameters which were located in quarter one of the circle it means the correlation of them with both F1 and F2 are positive significantly as shown in Table 15 and their locations depends on the values of correlation coefficient , also if the angle value between two vectors equal or more than 90 degrees it means there are significant correlation between them, and the angle greater than 90 degrees indicates to non-significant difference between them. In general the location of vectors in Figure (3 and 4) depends on the sign of factor(F I and F2).

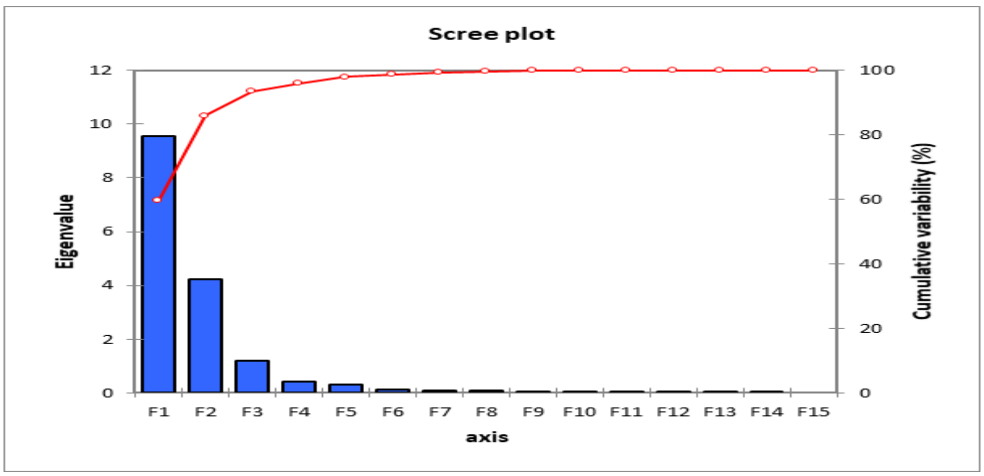

Fig.1. Scree plot for water parameters in north and north east of Erbil.

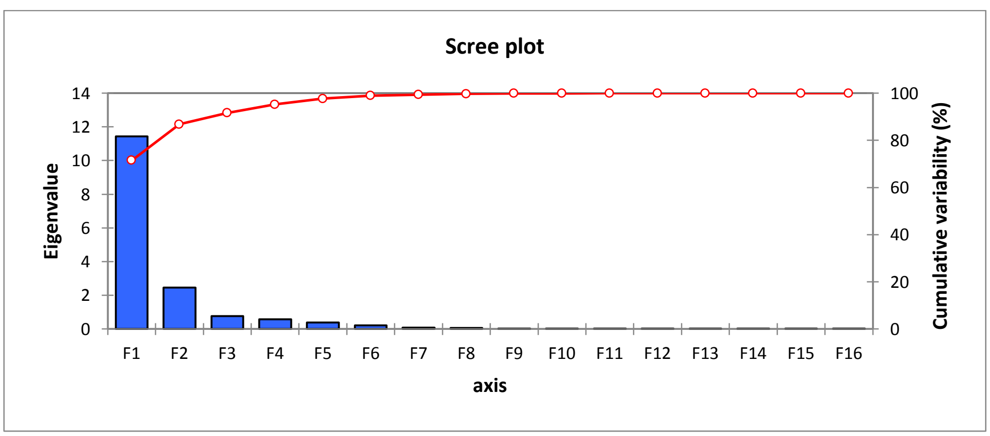

Fig.2. Scree plot for water parameters in south west of Erbil.

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Table 14. The eigenvalues, variability and cumulative variability for water of wells at both locations in Erbil.

		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}
North and north east	**Eigenvalue**	**9.53**	**4.23**	**1.19**	0.40	0.32	0.13	0.09	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Variability %	**59.58**	**26.47**	7.43	2.51	1.97	0.84	0.54	0.41	0.18	0.02	0.02	0.01	0.01	0.00	0.00	
	Cumulative %	**59.58**	**86.05**	**93.48**	95.99	97.97	98.81	99.35	99.76	99.94	99.96	99.98	99.99	100.00	100.00	100.00	100.00
South and south west	**Eigenvalue**	**11.44**	**2.45**	0.77	0.58	0.38	0.21	0.07	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	Variability (%)	**71.50**	**15.32**	4.80	3.63	2.40	1.30	0.44	0.33	0.18	0.06	0.03	0.01	0.00	0.00	0.00	0.00
	Cumulative %	**71.50**	**86.82**	91.62	95.25	97.66	98.96	99.39	99.72	99.90	99.96	99.99	99.99	100.00	100.00	100.00	100.00

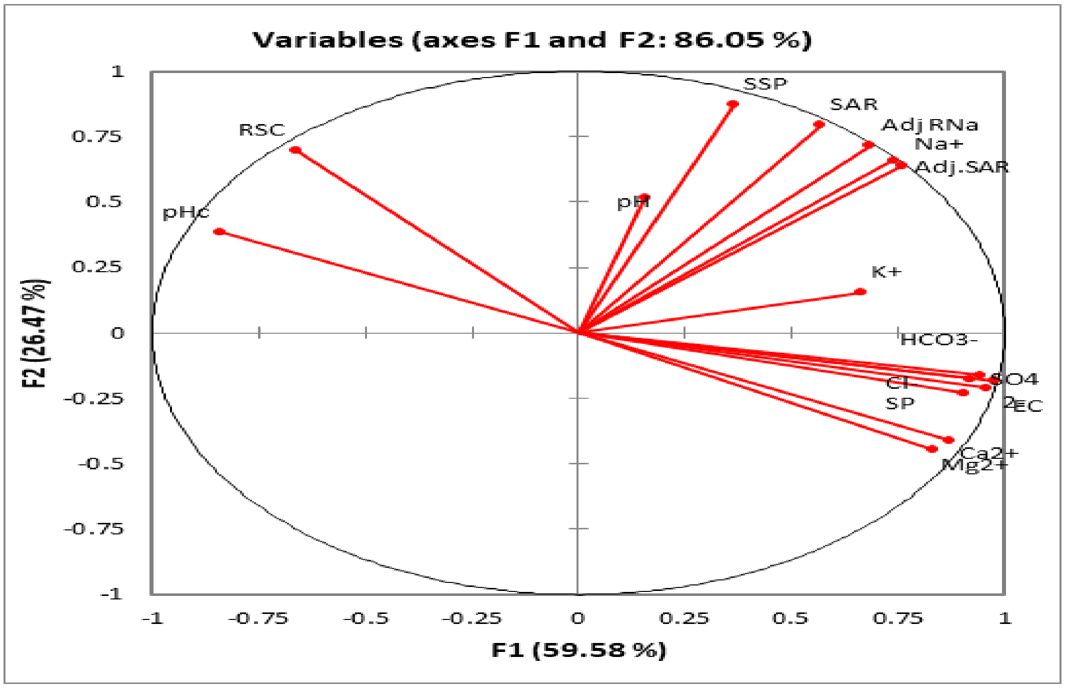

Fig.3. Plot vectors for water of north and north east of Erbil.

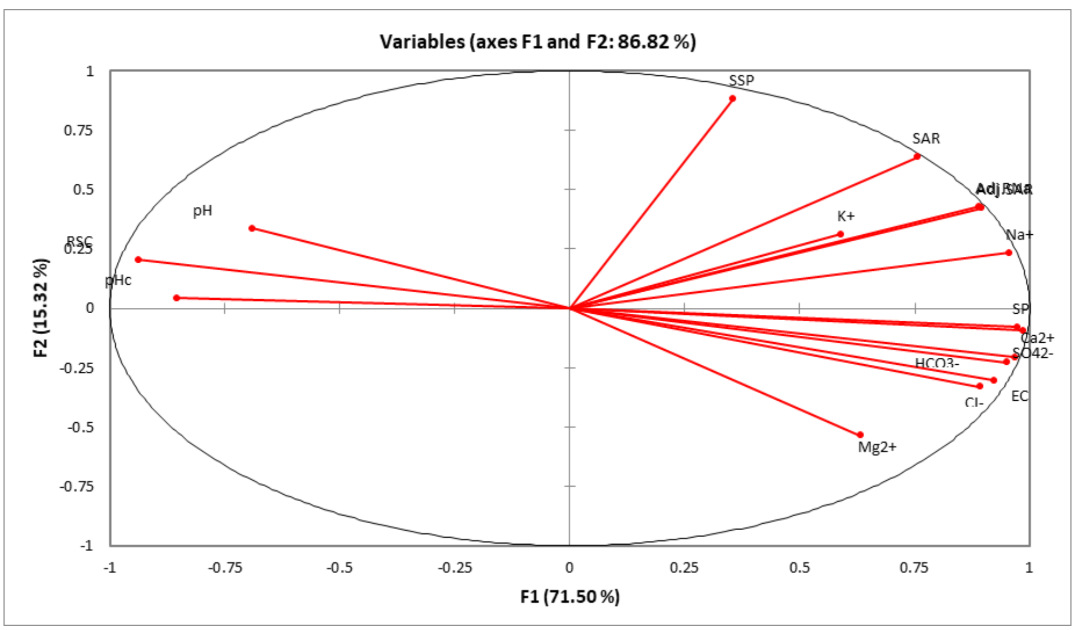

Fig.4. Plot vectors for water of south west of Erbil.

Table 15. Factor loadings between variables and factors from the water samples in South east of Erbil.

Variables	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
EC	0.97	-0.21	0.06	-0.06	0.10	0.00	0.05	-0.01	0.02	-0.01	-0.01	0.01	0.01	0.00	0.01	0.00
pH	-0.69	0.34	0.52	-0.19	0.03	0.32	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pHc	-0.85	0.04	0.05	0.04	0.50	-0.08	-0.07	-0.09	-0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ca^{2+}	0.95	-0.23	0.01	0.02	0.19	0.06	0.04	0.02	0.03	-0.04	-0.01	-0.01	0.00	0.00	0.00	0.00
K^{+}	0.59	0.31	0.54	0.49	-0.02	-0.15	0.03	0.02	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na^{+}	0.96	0.23	-0.11	0.02	0.06	0.05	0.09	-0.02	0.00	0.07	-0.01	-0.01	0.00	0.00	0.00	0.00
Mg^{2+}	0.63	**-0.54**	0.35	-0.36	-0.17	-0.15	-0.04	-0.08	-0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
SO_4^{2-}	0.99	-0.09	0.01	0.04	0.04	0.05	0.02	-0.09	0.04	-0.01	-0.04	0.00	-0.01	0.01	0.00	0.00
HCO_3^-	0.92	-0.30	0.09	-0.14	0.11	-0.01	0.12	0.00	0.00	-0.01	0.04	0.00	0.00	0.00	0.00	0.00
Cl-	0.89	-0.33	0.11	-0.12	0.18	-0.01	-0.10	0.16	0.00	0.02	-0.01	0.00	0.00	0.00	0.00	0.00
RSC	-0.94	0.20	0.01	-0.19	0.09	-0.12	0.12	0.06	-0.03	0.00	-0.01	0.01	0.00	0.01	0.00	0.00
SAR	0.76	**0.64**	-0.06	-0.13	-0.01	-0.02	-0.05	0.00	-0.05	-0.02	-0.01	-0.01	0.02	0.00	0.00	0.00
Adj.SAR	0.89	0.42	-0.13	-0.05	0.00	0.01	-0.01	0.01	-0.06	0.00	0.00	0.02	-0.01	0.00	0.00	0.00
Adj RNa	0.89	0.43	-0.12	-0.04	0.04	0.04	0.00	-0.01	-0.07	-0.02	0.01	-0.01	-0.01	0.00	0.01	0.00
SP	0.97	-0.08	-0.05	0.14	-0.03	0.11	-0.09	-0.03	0.01	0.02	0.03	0.01	0.00	0.01	0.00	0.00

*Values ≥ 0.47 means the significant relation between variables and loading factors

For Table 15, F1 =EC, pH, pHc, Ca^{2+} ,K^+, Na^+, Mg^{2+} ,SO_4^{2-}, HCO_3-, Cl-, , RSC, SAR ,Adj.SAR , Adj.RNa and SP.

F2 = Mg and SAR.

Other factors can be neglect since there is no significant correlation or loadings among variables and (F3 to F16).

For table (3.4) F1 = EC, pHc, Ca^{2+} ,K_+, Na_+, Mg^{2+} ,SO_4^{2-}, HCO_3^-, Cl^-, RSC, SAR,Adj.SAR , Adj.RNa and SP.

F2=pH, Na, RSC, SAR, Adj.SAR, Adj.RNa and SSP.

F3 =pH, and K.

Other factors can be neglect since there is no significant correlation or loadings among variables and (F4 to F16).

Conclusion

The results indicated that the studied groundwater are differing in their quality among wells or locations and depending on the applied global classification for irrigation water. In general, the water quality in north and north east of Erbil is better than those in south west of Erbil. The principal component analysis (PCA) regards as a best method for studying and limiting the factors depending on their significant effect and importance. **Recommendations:**

Depending on the obtained results the following recommendations were created:

1. Classification the groundwater for different uses.
2. Comparison between cluster analysis and Principal component analysis in future studies.

Table 15. The loading values among variables and factors for the water samples in north and north east of Erbil.

Variables	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
EC	0.98	-0.18	0.00	-0.05	-0.05	-0.01	0.04	0.02	0.00	0.01	0.03	-0.02	-0.01	0.01	0.00	0.00
pH	0.16	**0.51**	**0.78**	-0.14	0.24	0.14	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pHc	-0.84	0.39	0.02	0.30	0.03	-0.09	0.19	0.05	-0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ca^{2+}	0.87	-0.41	0.00	-0.05	-0.22	0.08	0.09	0.09	0.03	0.01	0.00	0.01	0.01	0.00	0.00	0.00
K^{+}	0.66	0.15	**0.63**	0.27	-0.19	-0.16	-0.07	-0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na^{+}	0.76	**0.64**	-0.05	-0.01	-0.03	-0.02	-0.03	0.03	-0.05	0.02	-0.01	-0.02	0.01	-0.01	0.00	0.00
Mg^{2+}	0.83	-0.45	0.05	-0.09	0.22	-0.15	0.05	-0.14	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO_4^{2-}	0.94	-0.16	-0.13	-0.01	0.19	-0.11	-0.03	0.14	0.00	-0.02	-0.02	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	0.92	-0.18	0.10	-0.24	-0.19	-0.04	0.12	-0.04	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
Cl^{-}	0.90	-0.23	-0.01	0.29	-0.02	0.19	0.00	-0.09	-0.03	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
RSC	-0.66	**0.70**	0.09	-0.16	-0.18	-0.01	-0.01	-0.04	-0.04	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.00
SAR	0.57	**0.80**	-0.20	0.03	0.04	0.01	0.01	0.00	0.02	-0.03	0.03	0.01	-0.01	-0.01	0.00	0.00
Adj.SAR	0.74	**0.66**	-0.08	-0.05	-0.03	0.00	-0.08	0.01	-0.04	0.03	0.00	0.02	-0.01	0.00	0.00	0.00
Adj RNa	0.68	**0.72**	-0.13	-0.02	-0.02	-0.01	-0.02	-0.01	-0.03	-0.01	0.01	0.00	0.02	0.01	0.00	0.00
SP	0.96	-0.21	-0.06	0.17	0.07	0.07	-0.01	0.01	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
SSP	0.36	**0.87**	-0.27	0.05	0.06	0.01	0.08	-0.05	0.11	0.01	-0.02	0.00	0.00	0.00	0.00	0.00

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