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RESEARCH PAPER

Limiting Irrigation Water Quality Indices of several rivers, wells and springs in Dohuk governorate

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A B S T R A C T:

The investigation was done during 2018, that included the chemical analysis of 30 water samples which were taken from 10 wells,10 springs and 10 rivers in Dohuk. The results showed that 10 , 26.67 , 53.33 and 10% of tested water samples had excellent ,good, average and poor quality relying on quality index for irrigation water and Brazilian classification(2012) that located between zero to 13.34.On the other hand depending on Meireles *et al.*, classification (40 ,40 ,16.67 and 3.33) percentage of the studied water resources recorded medium , high ,severe and low restriction of applying for irrigation uses respectively with the quality index for irrigation of (37.38 to 42.02). The results showed the difference between the results of two applied systems for irrigation water category.

KEY WORDS: Index for irrigation water., Water resources, Water classification.
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1. INTRODUCTION:

The irrigation water quality index (IWQI) regards as modern method for classification of water resources for irrigation and other purpose. Nasly et al., (2013) indicated that water resources regard as one of the most important and necessary natural resources in the world and Kurdistan region for different uses such as irrigation, livestock, animals, fish culture, irrigation, drinking and industrial. The amount of water is 2/3 of the earth and only 2-3% of it had good quality or fresh water as mentioned by Ambiga and Durai,2012).

The index of water quality is a type of average recorded from a numerous variable then combined in one datum or obtained from combining of several variables and sub-indices to a single value. Yogendra and Puttaiah (2008) explained that the irrigation water quality refers to a single value or number which represent the water quality for a water quality at a certain location, relying on some water properties.

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On the other hand, water quality index means obtain of one value from large number of data then expressing it in a simple scientific term like bad, medium, good or bad category (Bharti and Katyal,2011).

Water quality expressed as water quality index (WQI) to assess whether water is suitable or not (Singh and khan, 2011).

Developing of water quality index for irrigation purpose (IWQI) depended on standards of water quality obtained by Ayers and Westcott(1985).At last two decades the water quality index for irrigation purpose used in wide range for determination of water resources quality which regards as a very useful method to obtain information on water quality which depends on water chemical composition or dissolved salts as explained by Al-mussawi,2014).

The water quality index for irrigation of Euphrates, Tigris in addition to Shat Al-Arab in Iraq was studied by Al-meini (2010). The obtained data referred to the suitability of water samples taken from sites Feesh Kapour to Kut, while the water samples from Ali Algarbi location up to Amarah were moderately suitable.

Alhashmi and Mustafa (2012) showed that the irrigation water quality index of 14 samples taken from Euphrates ranged between “Good or low restriction “to “very poor or sever restriction of use”

The irrigation water quality index of 30 wells in Karbala city in wet and dry season was studied by Al-Mussawi (2014).The results indicated that their IWQI was varied between sever restriction(SR) to low restriction of use (LR).He indicated that (46.8 ,13.7,38 and 1.5) of water samples taken from wells had high, severe, moderate and low restriction of use respectively.

The Kani-Kani-Bani water stream of Tanjaro river/Sulaimani was tested by Hamasalh and Ahmad (2015) for irrigation purpose using (I.W.Q.I.), the results explained that the I.W.Q.I value for the studied water samples were within the category of excellent for irrigation.

Hanna and Shekha (2017) studied water quality index of Zar Gali stream. Bikhal and Khalan river in Erbil governorate for environmental purpose.

Rajab and Esmail (2021) grouped the water for 22 springs on both wet and dry season in north Erbil /Kurdistan region depending on (I.W.Q.I). The results showed that 15 and 7 springs had excellent and good water class respectively. On the other hand, calculating IWQI from EC values the water for (13 ,5, and 4) springs in wet season and water for (12 ,4 and 4) springs in dry season had had excellent, good and poor class respectively.

Large number of researches were done on classification of groundwater in Kurdistan region and Iraq for irrigation purpose in last decade but only some of this investigation depended on irrigation water quality index for irrigation water classification (IWQI) purpose (Rajab, 2015 and Rajab and Esmail, 2022). For this reason, this study depended on I.W.Q.I.

2.MATERIALS AND METHODS:

This investigation was done in Duhok governorate, IKR during October 2019 after taking 30 water samples from different water resources rivers, springs and well it means 10 sample from each of the water resources the tested locations and their GPS reading was shown in table (1) and figure (1).

The most important water chemical properties for water samples were analyzed depending on APHA (1989).

Table 1. Shows the GPS reading of the studied locations:

Water resources	Name	N	E
Rivers	1-Nahnahk	37° 12' 04"	43° 12' 57"
	2-Ze trwanish	37° 11' 04"	43° 36' 18"
	3-Benarinke	36° 53' 12"	43° 14' 26"
	4-Solav	37° 06' 17"	43° 29' 04"
	5-Bedohe	37° 15' 43"	43° 24' 38"
	6-Stkork	36° 56' 05"	43° 12' 21"
	7-Ze serye	37° 11' 4.6"	43° 36' 17"
	8-Bedol	36° 51' 59"	43° 14' 07"
	9-Reye shin	37° 03" 06"	43° 52' 49"
	10-khabor	37° 08' 59"	42° 40' 44"
Wells	1-Aloka	36° 50' 17"	42° 55' 25"
	2-Meseric	36° 51' 36"	42° 49' 24"
	3-Batel	36° 57' 51"	42° 39' 57"
	4-Telkhesh	36° 46' 11"	43° 02' 14"
	5-Qarqarava	36° 54' 34"	43° 01' 22"
	6-Summel	36° 51' 36"	42° 52' 11"
	7-Hamid blala	36° 51' 54"	42° 50' 26"
	8-Tanahi	36° 51' 36"	42° 54' 20"

	9-Seje	36° 54' 46"	42° 52' 52"
	10-Dlebe	36° 50' 56"	42° 54' 23"
Springs	1-Bedoh	37° 15' 10"	43° 25' 08"
	2-Avsarke	37° 10' 57"	43° 34' 37"
	3-Zawita	36° 54' 26"	43° 10' 18"
	4-Bablo	36° 52' 22"	43° 07' 30"
	5-sharmen	36° 48' 09"	43° 43' 28"
	6-kozo	36° 52' 00"	43° 08' 02"
	7-Serye	37° 01' 01"	43° 48' 45"
	8-Bamarne	37° 07' 10"	43° 16' 15"
	9-Kani balave	37° 10' 40"	43° 10' 47"
	10-Biyave	37° 01' 50"	43° 41' 39"

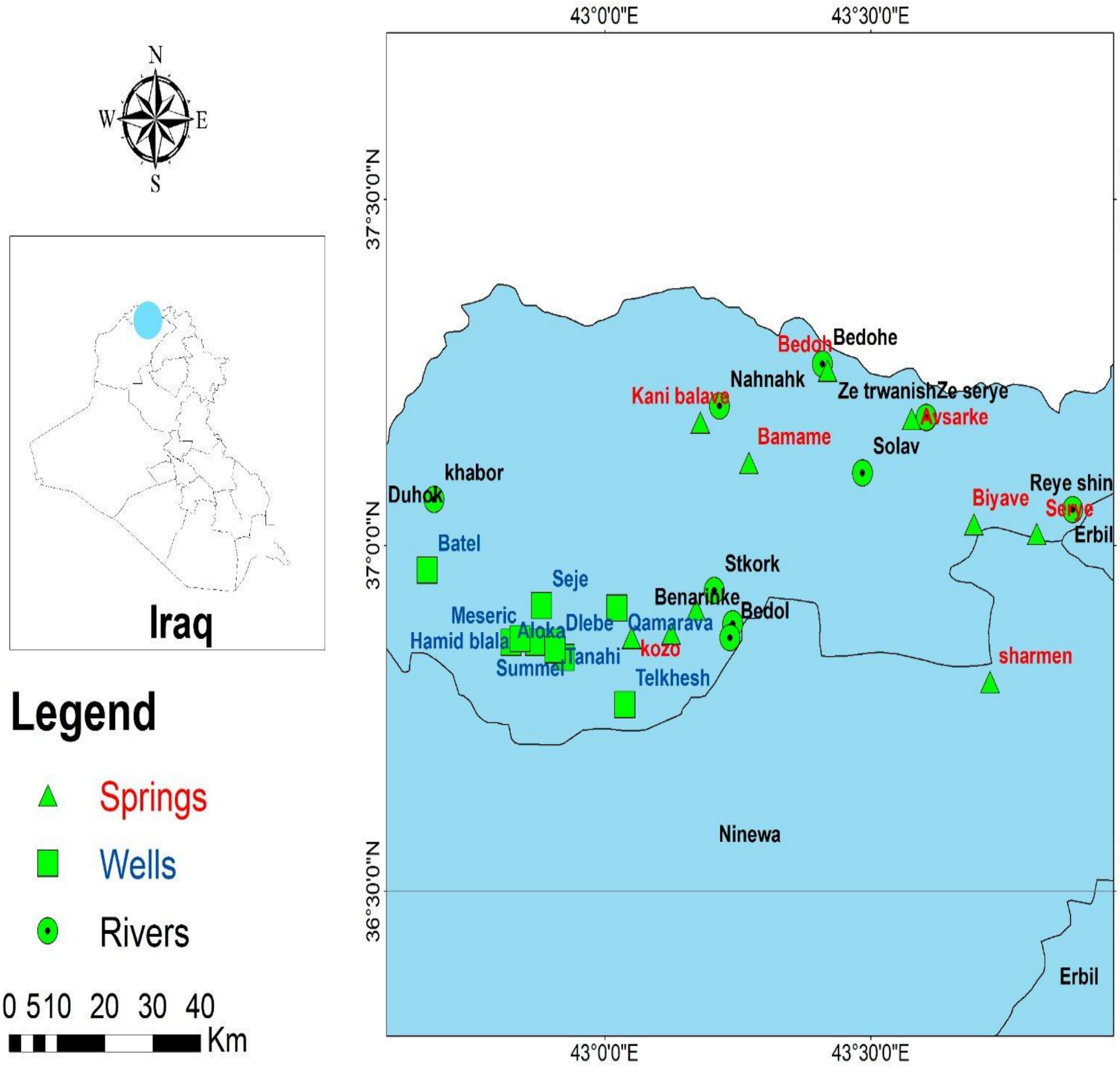

Figure 1. Map of the studied locations for the selected water resources in Dohuk governorate.

2.1. Determination of irrigation water quality indices (IWQI):

The main two methods for determining IWQI are:

2.1.1. First: Meireles et al., (2010) method which includes the following steps:

1-Identified the parameters were considered more relevant to the irrigation use (EC, Na^+, HCO_3^-, Cl^-, SAR).

2-The values of quality measurement (Quality rating) (Qi) for each parameter were calculated using the equation (1), based on the tolerance limits shown in (table,2), and the observed water quality results. Table (2) was consecrated according Ayers and Westcot (1999).

Qi= qimax - ([Xij -Xinf)*qiamp]/xamp------------(1)

Where q_{imax} = The maximum value of quality rating scale (qi) for the class of (table, 2) .

X_{ij} = The observed value for the parameter.

X_{inf} = The corresponding value to the lower limit of the class to which the parameter belongs; q_{iamp} is class amplitude; x_{amp} is class amplitude to which the parameter belongs .In order to evaluate x_{amp}, of the last class (category) of each parameter, the upper limit was considered to be the highest value determined in the physical-chemical and chemical analysis of the water samples.

3- The weight of each water parameter has been assigned according to its relative importance in the overall quality of irrigation water (table ,3). Function of its relative importance the quality of ground water and the division in categories (classes) as mentioned by Meireles et al., (2010) was recorded in table (4):

Table 2. Parameter limiting values for (Qi) calculation (Ayers and Westcot, 1985) depending on real classes.

IWQI	EC (dS m^{-1})	SAR°$(meql^{-1})^{1/2}$	Na^+	Cl^-	HCO_3^-
			Meq L^{-1}		
85-100	0.20 - 0.75	2 - 3	2 - 3	1 - 4	1 - 1.5
60-85	0.75 - 1.5	3 - 6	3 - 6	4 -7	1.5 - 4.5
35-60	1.5 -3.00	6 - 12	6 - 9	7 - 10	4.5 - 8.5
0-35	0.20 -- 3.00	2 - 12	2 - 9	1 - 10	1 8.5

Table 3. Weights for the (IWQI) parameters (Meireles et al., 2010).

Parameters	Wi
Electrical Conductivity (EC)	0.211
Sodium (Na^+)	0.204
Chloride (Cl^-)	0.194
Bicarbonate (HCO_3^-)	0.202
Sodium Adsorption Ratio (SAR)	0.189
Total	1.00

Table 4. Water classes according to Meireles et al., (2010)

Water quality index for irrigation (I.W.Q.I.)	Restriction of use (water class)
85 to 100	N.R. = there is no restriction of use for irrigation
70 to 85	L.R. =There is low restriction of use for irrigation
55 to 70	M.R. =The restriction is moderate.
40 to 55	H.R. = The restriction is high.
0 to 40	S.R. =The restriction is severe.

Table 5. Irrigation water classification according to Mia and Rodrigues (2012).

Water class	I.W.Q. value
Class one = Excellent	Equal or less than 1.96
Class two = Good	From 1.96 to 5.88
Class three = Average	From 5.88 to 8.80
Class four = Poor	Less than 9.80

2.1.2. The second determination (Maia and Rodrigues,2012) that included the following steps:

1-Calculating the standard deviation from the reference values for each of the studied properties, then conducting normalizing of data using the following model:

Zi = (Xi -X⁻) /sigma------------------------(3).

Zi = The normalized value for the studied water properties.

X =Value of the determined property for water sample.,

X⁻ =Mean of reference population for the same property.

Sigma = The statistical standard deviation for the reference population.

2- Calculating the I.W.Q.I. for the chemical properties (EC, pH, Ca, Mg, Na, K, CO_3, HCO_3 ,SO_4 , RSC ,SP and SAR) as shown below:

3- W.Q.I.i = SQR $(Zi)^2$ -------------------(4)

Then calculating I.W.Q.I. as follow:

I.W.QI. =1/N Σ WQIi, I from 1 to n -----(5)

3- Calculating the IWQI as follow:

Where WQIi = water quality index for irrigation for each property.

I.W.Q.I. =Irrigation water quality index,

IWQI = Irrigation Water Quality Index.

Depending on classification of Mia and Rodrigues (2012) the irrigation water classified as follow depending on their I.W.Q.I. values.

3.RESULTS:

The parameter˒s mean values for the studied water resources were recorded in table (6,7 and 8), while their IWQI values were recorded in table (9).

According to Maia and Rodrigues irrigation water classification (2012) and depending on water chemical analysis and irrigation water quality index values, one, four and five river water samples recorded excellent, good and medium class that equivalent to 10,40 and 50% of river water samples respectively (table 6 and 9) and figure (2).

On the other hand, table (9) and figure (3) indicated that ten, twenty and seventy percentage of the studied waters taken from wells had excellent, good and medium class respectively.

As shown from table (9) and figure, 3) that 10, 20 and 70% of the studied well waters had excellent, good and average class respectively.

The obtained results from table (9) and figure (4) explained that the spring water samples had hand excellent, good, average (medium), and poor classes with 10,20 ,50 and 20 % respectively which equivalent to 1, 2,5 and 2 spring water samples.

Finally, the results indicated that the percentage of excellent, good and average water classes for the studied water samples (water resources) in Dohuk governorate were10 ,26.67 .53.33 and 10% respectively. Figure (4) Radar shape for water classes for spring waters according to Maia and Rodrigues (2012).

While according to Meiriles et al., irrigation water classification (2010), eight and two water samples of rivers had moderate and high restriction for irrigation use respectively.

Referring to water samples taken from wells 5 ,4 and 1 of the tested wells had high, moderate and low restriction of use for irrigation purpose. On the other hand, 5 of the spring water samples had severe restriction of use and other 5 samples had high restriction of use (table,9 and figure 7).

The overall results indicated that the percentage of medium, high, severe and low restriction of use of the studied water samples were (40 ,40, 16.37 and 3.33) % of the studied water resources respectively (table,9).

Table 6. Explains chemical analysis of the studied river waters.

No.	Rivers	pH	EC dS m^{-1}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}
1	Nahnahk	7.76	0.60	2.10	2.00	0.60	0.04	0.60	2.80	0.0	1.34
2	Ze trwanish	6.95	0.45	1. 60	0.80	1.20	0.03	0.40	2.70	0.0	0.53
3	Benarinke	7.73	0.82	3.50	2.00	1.80	0.06	0.80	4.50	0.0	2.66
4	Solave	7.68	0.55	1.90	0.80	1.20	0.04	0.60	2.50	0.0	0.84
5	Bedoh	7.8	0.63	2.40	1.80	1.20	0.07	0.70	3.60	0.0	1.17
6	Stkork	7.55	0.76	3.00	1.60	1.00	0.11	1.10	3.30	0.0	1.31
7	Ze serye	7.29	0.46	1.80	0.70	1.60	0.06	0.50	3.00	0.0	0.66
8	Bedol	7.81	0.78	3.00	1.50	1.50	0.06	0.70	3.60	0.0	1.76
9	Reye shin	7.93	0.44	1.30	0.80	1.00	0.05	0.40	1.70	0.0	1.05
10	Khabor	7.36	0.49	2.00	1.00	0.80	0.08	0.80	2.20	0.0	0.88

Table 7. Explains the results for chemical analysis of the studied well waters.

No.	Well	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}
1	Aloka	7.32	0.99	3.90	2.20	1.80	0.13	1.30	4.75	0.0	1.98
2	Meseric	7.62	0.98	4.40	3.20	1.40	0.11	1.50	5.10	0.0	2.50
3	Batel	7.49	0.85	4.00	2.40	1.10	0.09	1.20	4.30	0.0	2.09
4	Telkhesh	7.54	0.84	2.30	2.70	2.60	0.12	0.80	4.20	0.0	2.72
5	Qarqarava	7.94	0.96	3.70	3.80	0.80	0.14	1.10	4.90	0.0	2.44
6	Summel	7.84	0.95	5.00	3.90	1.20	0.03	1.40	4.37	0.0	4.36
7	Hamid blala	8.04	0.75	2.00	2.79	2.00	0.04	1.20	3.83	0.0	1.80
8	Tanahi	7.85	0.68	3.80	2.88	0.80	0.07	0.80	3.66	0.0	3.09
9	Seje	7.88	0.77	3.20	1.80	1.40	0.10	0.90	4.00	0.0	1.60
10	Dlebe	7.32	0.71	3.40	1.60	1.20	0.13	0.75	3.77	0.0	1.81

Table 8. Explains chemical analysis of the studied spring waters.

No.	Spring	pH	EC dS m^{-1}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}
1	Bedoh	7.35	0.67	4.30	1.90	0.88	0.11	0.40	4.50	0.0	2.29
2	Avsarke	7.45	0.64	3.90	2.30	1.30	0.12	0.70	5.20	0.0	1.72
3	Zawita	7.7	0.67	4.00	2.60	0.90	0.08	0.90	4.88	0.0	1.80
4	Bablo	7.88	0.55	3.50	2.40	0.50	0.04	0.70	4.99	0.0	0.75
5	Sharmen	8.17	0.45	2.80	2.20	0.60	0.02	0.50	4.32	0.0	0.81
6	Kozo	7.36	0.75	3.80	2.50	0.50	0.04	0.80	3.99	0.0	2.05
7	Serye	6.99	0.8	4.10	2.00	0.70	0.06	0.75	3.56	0.0	2.55

8	Bamarne	7.05	0.64	3.70	1.95	0.85	0.07	0.80	3.80	0.0	2.02
9	Kani balave	7.3	0.58	2.50	1.02	1.50	0.07	0.95	2.88	0.0	1.44
10	Biyave	7.7	0.53	2.20	1.80	0.80	0.03	0.40	4.11	0.0	0.32

Table 9. Shows water classes depending on IWQI.

Water resources.			(Maia and Rodriguse (2012)	Water class	(Meiriles et al, 2010)	Water class
	NO.	Name				
Rivers	1	Reye shin	0	Excellent	63.33	MR
	2	Zetrwanish	5.84	Good	62.68	MR
	3	Ze serye	4.30	Good	64.58	MR
	4	Khabor	3.72	Good	45.87	HR
	5	Solav	6.14	Average	62.06	MR
	6	Nahnahk	4.33	Good	41.36	HR
	7	Bedohe	6.52	Average	58.97	MR
	8	Stkork	8.20	Average	57.06	MR
	9	Bedol	7.27	Average	59.71	MR
	10	Benarinke	8.95	Average	59.26	MR
Wells	1	Tanahi	1.00	Excellent	43.78	HR
	2	Dlebe	6.84	Average	43.82	HR
	3	Hamid blala	5.30	Good	73.35	LR
	4	Seje	4.72	Good	43.56	HR
	5	Telkhesh	6.14	Average	56.22	MR
	6	Batel	7.43	Average	56.19	MR
	7	Summel	6.52	Average	53.42	HR
	8	Qarqarava	8.20	Average	54.67	HR
	9	Meseric	7.67	Average	56.59	MR
	10	Aloka	9.74	Average	58.16	MR
Springs	1	Sharmen	1.10	Excellent	38.88	SR
	2	Biyave	2.91	Good	39.42	SR
	3	Bablo	3.99	Good	37.88	SR
	4	Kani Balave	9.55	Average	49.31	HR
	5	Bamarne	8.87	Average	42.01	HR
	6	Avsarke	13.34	Poor	41.35	HR
	7	Zawita	10.00	Poor	40.84	HR
	8	Bedoh	12.25	Poor	38.03	SR

	9	Kozo	6.76	average	39.06	SR
	10	Serye	9.41	average	40.27	HR

4.DISCUSION:

The obtained water classes for the studied rivers could be due to their IWQI values which ranged between 0,0 to 8.95 (Table 9 and Figur,2).

The water classes for spring may be due to their IWQI values which located between 1.10 and 13.34(table,9).

The water classes relying on IWQI values for the studied water resources were explained in radar shapes (figures 2,3 and 4) according to Maia and Rodrigues (2012). Radar shapes explaining that shifting of water samples or their locations to words the outer circle means decrease in water quality and via versa similar results was recorded by Rajab and Esmail 2021 and 2022).

The water classes for rivers water samples according to Meiriles et al., classification (2010) was due to their IWQI which was ranged between 41.36 – 64.8.It means 80% of the studied rivers had moderate restriction(MR) class, while 20% had high restriction of use class for irrigation due to the reasons mentioned before (table,9 and figure,4).

The classes of well water samples according to Meiriles et al., classification (2010) may attributed to the IWQI of them which located between 43.56 and 73.35 (table, 9 and radar shape or figure,6). The spring water classes was due to IWQI value that located between 37.38 to 42.02. The categories of irrigation water depending on irrigation quality index (IWQI) values were varying among the studied water resources, and also varying among water samples taken from different locations for the same water resource. On the other hand, the irrigation water quality indices values were differing depending on method of classification and parameters included in it.

(table, 9 and radar shape or figure,7). The overall classes of the studied water resources in Dohuk governorate were related to their IWQI values (37.78 to 73.36). The results explained that the two mentioned classifications recorded different results. This results agree with those obtained by Rajab (2015).This may be due to the following reasons: In the second water classification or Maia and Rodriguse classification(2012) all the studied water parameters were included in calculating IWQI or there is no limitation in number of parameters such as main cations ,anions ,micronutrients ,heavy metals, EC, pH , sodium adsorption ratio (SAR), salinity potential(SP) residual sodium carbonate ----etc, and all chemical properties of irrigation water using in calculating IWQI. While the first classification or Meriles et al., (2010) depended on five parameters only (EC, pH, SAR, HCO_3 and Cl) in calculating IWQI values which caused the variation between the two mentioned classification. The second classification regards as a better one in comparing with the first one due to the limitation in using number of parameters in the first classification for calculating IWQI values. This result agrees with the results of Rajab (2015) depending on her results in laboratory and field experiments.

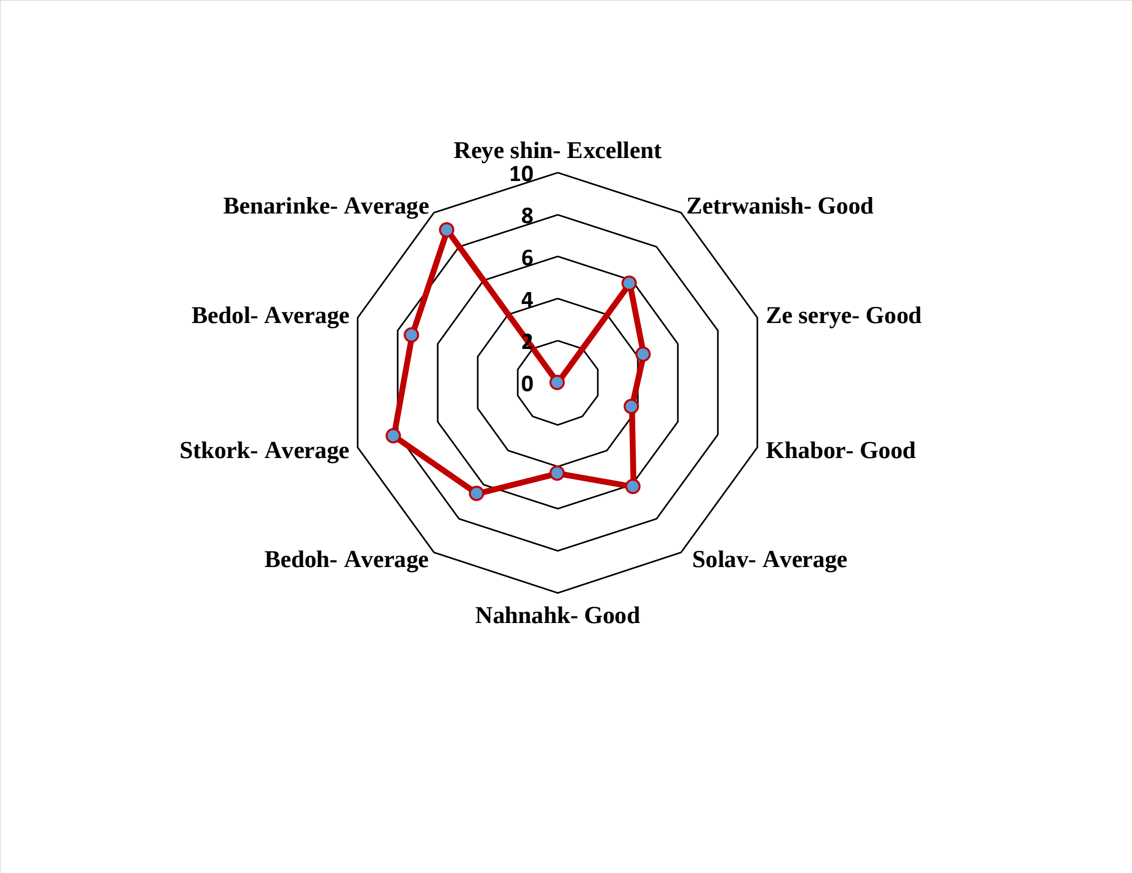

Figure 2. Explains radar shape for IWQI for rivers water according to (Maia and Rodrigues ,2012)

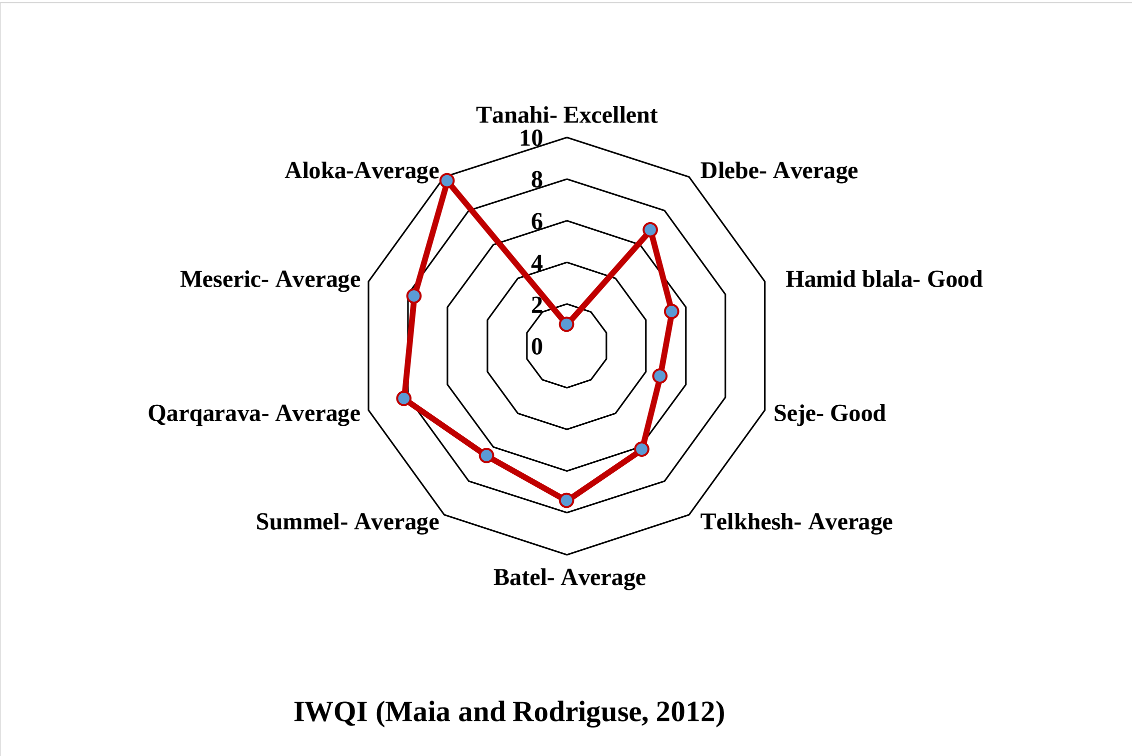

Figure 3. Radar shape for well water classes according to Maia and Rodrigues(2012).

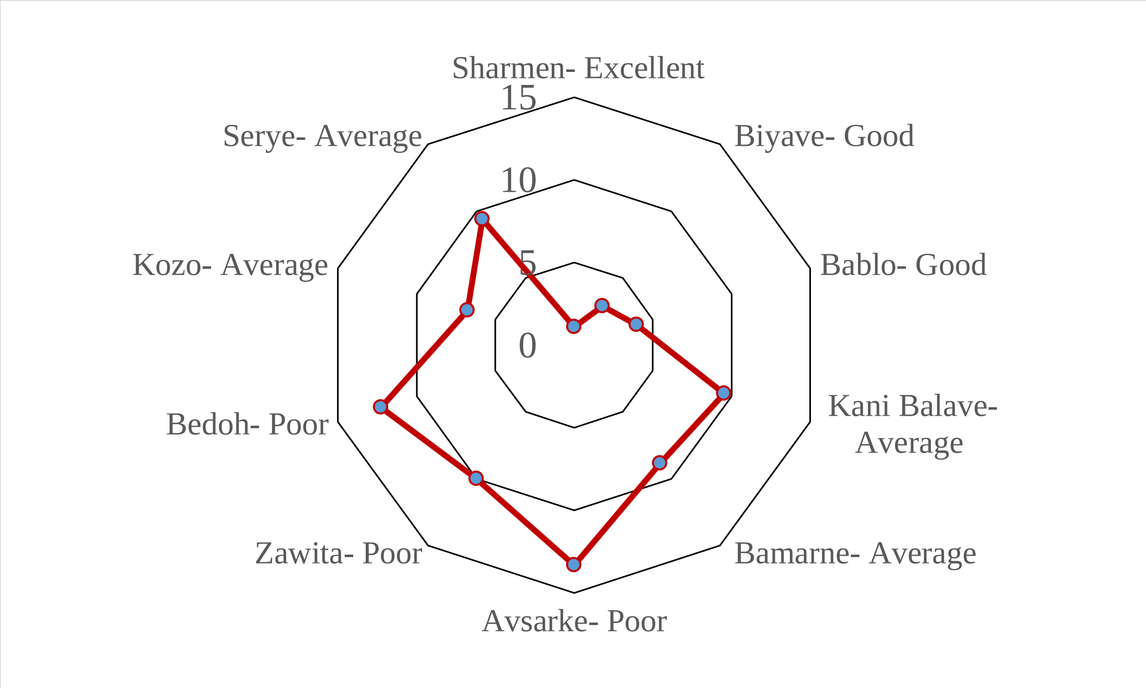

Figure 4. Radar shape for water samples taken from rivers (Maia Rodriguse (2012).

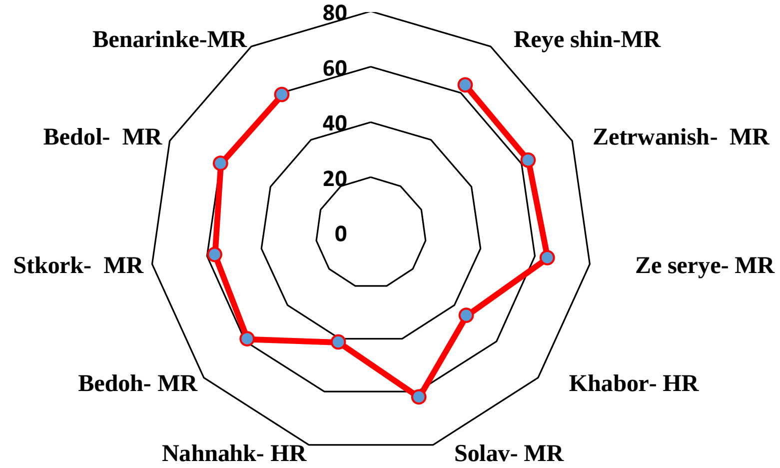

Figure 5 . Water classes depending on IWQI values for rivers water (Meireles *et al*, 2010)

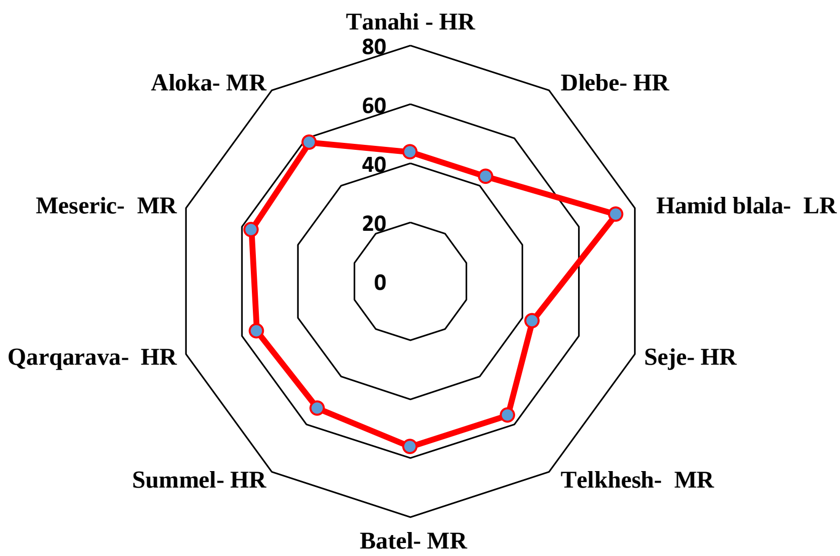

Figure 6. Radar shape for well water samples depending on IWQI(Meireles et al, 2010)

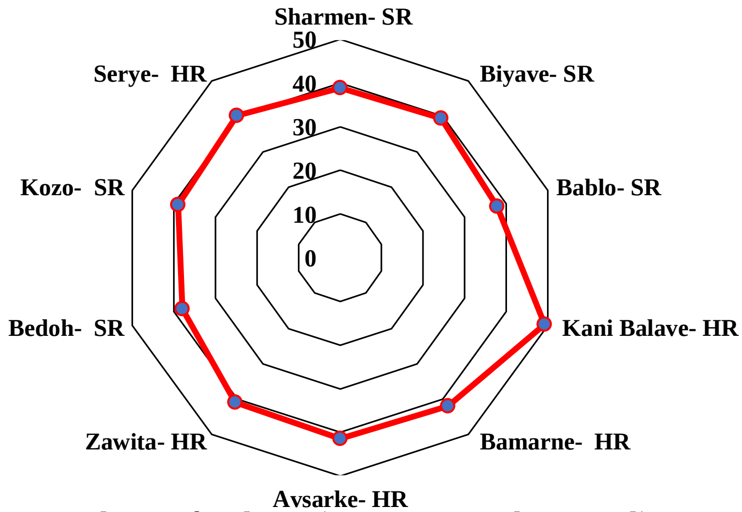

Figure 7. water classses for the spring water samples according to IWQI(Meiriles et al, 2010)

5.CONCLUSION:

The water quality and water classes depending on irrigation quality index (IWQI) were varying among the studied water resources, and also varying among water samples taken from different locations for the same water resource. On the other hand, the irrigation water quality indices values classes or categories were recorded for the studied water resources depending on the selected methods for water classification and parameters included in each method of classification.

6.Akhnolegement:

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