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Survey of Hydro-geochemical Quality of Important Rivers in Azna, Lorestan Province, Iran

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A B S T R A C T

This research was conducted to compare the water quality of the major rivers of Azna city in Lorestan province. For this purpose information on the chemical parameters of the 4 rivers of Kamandan, Marbareh, Darehtakht and ChamZaman was prepared in the April of years 2001, 2006, 2012, 2016 and 2017.For compare the water quality of these rivers for drinking, farming and determining the water type, Shouler, Wilcox and Piper charts were drawn. Samples are within the range of WHO and ISIRI. Calcium has the highest amount of cation and The highest amount of anion is bicarbonate. The amount of SAR increased in rivers from years 2012 to 2016; Altogether, the Kamanan River in year 2017 has been of the best quality for farming and drinking.The quality of rivers in the city is good and in different years the important quality elements of rivers are in the standard of Iran and the world. The results of the Piper diagram show that the water type of the studied stations is calcium-bicarbonate and magnesium-bicarbonate. According to Schuler and Wilcox Diagrams, it can be concluded that overall the rivers have good quality for drinking and are suitable and slightly saline for agriculture.

1. Introduction

With growth and development in the world, surface water as rivers has gotten an extensive measure of contaminations from an assortment of sources [1]. Natural and human factors are causing changes in the physical, chemical and biological of water quality, so the science of water quality will be as an issue remain for engineers and scientists for the in next years [2].Suitable access to drinking water is considered as one of the important aspects of water management, strategic population management, and future planning for urban development in macro level. This is while access to healthy water for human use is one of today's concerns and it is still considered as a dream for one sixth of the world's population [3] [4]. It can undoubtedly be claimed that, if not more, the importance of water quality is not less than its quantity [5]. Understanding the factors and how and why water quality is changing over time in the source area is essentially required to develop appropriate management strategies for the protection of the groundwater resources and to ensure the safety and health of the drinking water [6].Urban development without a proper plan often results in environmental issues, for example, deterioration of water quality of rivers, lakes,

and reservoirs. In other words, the urban development causes human population and activities to increase and surrounding environment to be polluted. Therefore, the modern cities in western countries have been established through a comprehensive development plan including sewage collection and treatment. However, most cities in the south-eastern Asian countries have been developed without such a plan; wastewater generated from the cities often pollutes a receiving water body since it is discharged without a proper treatment [7].

2. Materials and Methods

2.1. The area of studying

Azna city in Lorestan province is located in west of Iran between the latitudes 49°27′N and longitudes 33°27′E, encompassing an area of about 1404.33 km^2 . Azna is located in the Zagros Mountains and has a cold and dry climate and the average altitude of the city is 1871 m above sea level. It is worth noting that the average rainfall is 650 mm, with the minimum and maximum temperature of -28.5 ° C and 33.3 ° C, respectively (Figure 1).This city has 3 important rivers. Until the year of 85, the Cham-Zaman river has been one of the important rivers in the city. Due to the drought and dam construction, this river is dry and its flooded only during the heavy rainfall time, this river has begun from the village of Dalian, and after passing from Azna and the village of Gorgi and Cham-Zaman, has arrived to the Dareh-Takht river. Dareh-Takht river originates from the mountain of Oshtorankooh to the river Marbareh. The Marbareh river is one of the rivers of the main of the Sezar and Dez river, where water is used for irrigation of the villages around the cities of Dorood and Azna. The Marbareh river originates from the mountain of Oshtorankooh(Figure 2).

2.2. Research method

In this research, that has been done with the aim of assessing the quality of surface water resources of the Azna city in different years, the statistical data of the rivers were collected from the Water Resources Administration of the city.

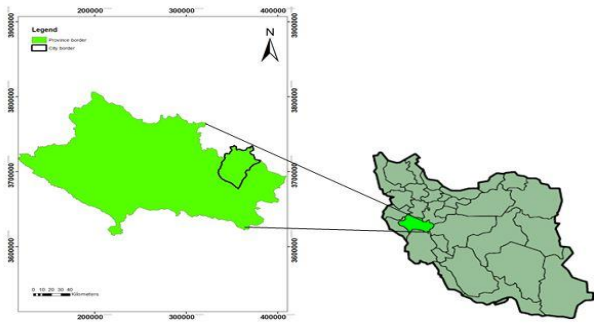

Figure 1. Geographical location of the city of Azna

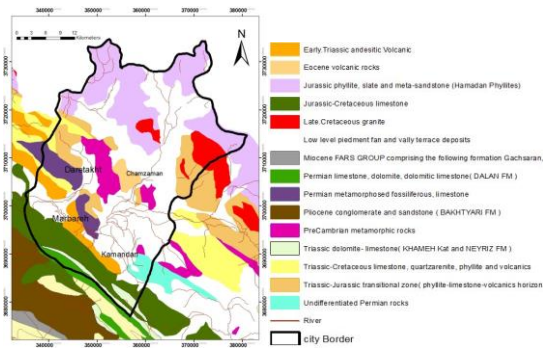

Figure 2. Geological map and location of sampling wells in the study area [8]

In the second step, in order to compare and process the parameters, charts of the important chemical parameters of the years under study were drawn in the Excel software environment . It should be noted that some parameters such as discharge, temperature and pH, in situ and some parameters such as the amount of anions, cations, hardness and TDS are measured in the laboratory. as well as information about the river Chamzman is available until the year 2006; this river in the year 2006 its dry and except during flood times, other times is dry and waterless . Qualitative charts were drawn every five years from 2001 to 2017, but due to the lack of data in the year 2011, in the month of April, the quality map was drawn in year of 2012. In the third step, the qualitative charts related to the elements were analyzed. Eleven important chemical parameters of water were measured; these parameters are: Total dissolved solids, anions (sulfate, chloride bicarbonate and carbonate), cations (magnesium, calcium, sodium and potassium), electrical conductivity, sodium absorption ratio and the acidity. Water graphic techniques are presented to make it

easier to interpret and analyze the results of water quality parameters. The most important of these methods are:, Schuler, Wilcox, Piper, diagram.

2.3. Schoeller Diagram

Semi-log diagram is using to show the primary ions on the base of equivalent millimeter per liter and also to show chemical differences between the samples used in a diagram. In hydrology reports for classification of drinking water usually Schuler diagram [9] is used. (Table 1) In this study also Schuler diagram [Figure 3], is used to assess the quality of drinking water.

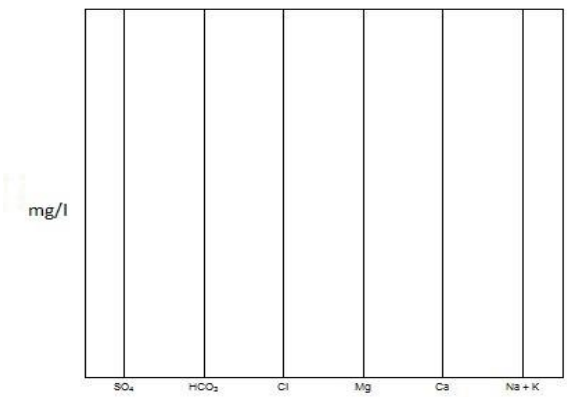

Figure 3.Schoeller diagram

Table 1. Classification criteria for drinking water according to Schuller opinion(mg /l)

TH	TDS	Cl^-	Na^+	SO_4^{2-}	Quality Type for drinking
<250	< 500	<175	<115	<145	Excellent
250 - 500	500 - 1000	175 - 350	115 - 230	145 - 280	Acceptable
500 - 1000	1000 - 2000	350 - 700	230 - 460	280 - 580	unsuitable
1000 - 2000	2000 - 4000	700 - 1400	460 - 920	580 - 1150	Bad
2000 - 4000	4000 - 8000	1400 - 2800	920 - 1840	1150 - 2240	Almost non-drinkable
>4000	>8000	> 2800	m>1840	m>2240	Non-drinkable

2.4. Wilcox Diagram

Wilcox chart [10], [Figure 4], is used for agricultural water classification. The Wilcox chart is provided based on two parameters, Electrical conductivity (EC) and a sodium absorption ratio (SAR) to determine the quality of agricultural water. The horizontal axis shows the amount of electrical conductivity to micromho/cm and the vertical axis, the SAR value [Table 2**].**

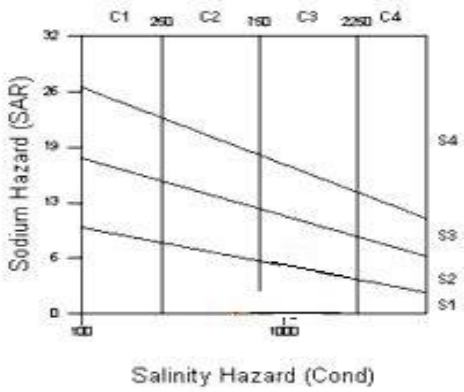

Figure 4. Wilcox diagram

Sodium Absorption Ratio (*SAR*)

Sodium risk, generally expressed as the ratio of sodium absorption (SAR),which is obtained by dividing sodium into calcium and magnesium. SAR is one of the most important parameters for determining the quality of agricultural water. This coefficient usually shows the amount of sodium ions, calcium and magnesium in the sample. The sodium adsorption ratio (SAR) values of each water sample were calculated by using equation [12]:

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

Table 2. Different classes of water and type of quality based on the Wilcox classification [13].

Water quality	EC (mho/cm)	Class	SAR	Class
Excellent	250>EC	C_1	SAR>10	S1
Good	750> EC>250	C_2	18>SAR>10	S2
Acceptable	250> EC >750	C_3	26>SAR>18	S3
Unacceptable	750> EC	C_4	26>SAR	S4

2.5. Piper diagram

One method of comparing the results of chemical analyses of ground water is with a trilinear diagram [11] (Figure 5). This diagram consists of two lower triangles that show the percentage distribution, on the milliequivalent basis, of the major cations (Mg^{2+} Ca^{2+}, and $Na^+ + K^+$) and the major anions (Cl^-, $SO_4^{2-}$and CO_3^{2-}+ HCO_3^-) and a diamond-shaped part above that summarizes the dominant cations and anions to indicate the final water type. This classification system shows the anion and cation facies in terms of major-ion percentages.

The water types are designated according to the area in which they occur on the diagram segments .

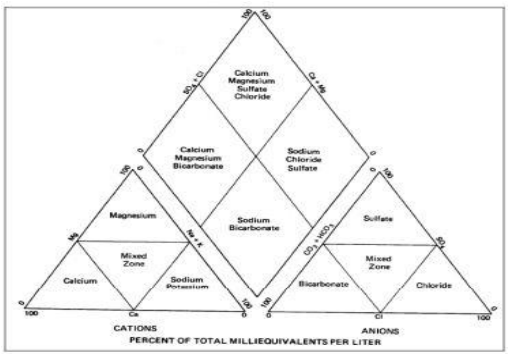

Figure 5. Piper diagram

2.6. Drinking water standards

Water quality is relative, and only by standards of water can be distinguished good quality water from poorly-quality water. In this research, the World Water Standard [13] and the Iranian Water Standard [14] have been used (Table 3).

Table 3. Standards for drinking water

Parameters	ISIRI 1053(5th.revision)	WHO: 2011
Ph	6.5-8.5	6.5-8.5
EC(µsemens/cm)		1000
TDS	1000	500
Na^{+}	200	200
K^{+}	-	12
Ca^{2+}	300	75
Mg^{2+}	30	50
Cl^{-}	250	250
CO_3^{2-}	-	-
HCO_3^{-}	-	120
SO_4^{2-}	250	250
NO_3^{-}	-	50
TH($CaCO_3$)	200	500

Note: All values except pH and EC are expressed in mg/l.

EC = Electrical Conductance (mho per centimeter).

TH = Total Hardness (mg /l $Caco_3^{2-}$).

WHO = World Health Organization.

ISIRI= Institute of Standards and Industrial Research of Iran.

3. Results & Discussion

Quality and quantity of water is one of the main pillars of sustainable development. On the other hand rivers has been introduced as one of the main available resources for human's needs that in addition to water quantity, the quality water is also an important determining parameter.

Table 4 and Table 5 show the values of the parameters in the April month af years 2001, 2006, 2012, 2016 and 2017 in the rivers. It should be noted that the lowest amount of discharge in rivers was 0.39 m^3/s for the Chamzaman river in the year 2001 and the highest rate of discharge is due to the year 2006 of the same river at 5.6 m^3 per second .Lowest discharge is in the Kamandan and Dareh- Takht rivers in the years of 2001 and 2017. Kammand River in year 2012 with a rate of discharge 2.45 m^3 and Dareh- Takht river in year 2016 with 2.67 m^3/s have the highest rate of discharge. The maximum of discharge in the Marbareh river in the year 2001, 5 m^3/s and its minimum value in this river was 1.5 m^3 per second in the year 2006.

Table 4. Ionic variation in ground water of Azna City

Year	Station	Ca	Mg	Na	K	Co_3	Hco_3	Cl	So4	Water Type
2001	Marbareh	3	2	0.09	0.06	0	3.3	0.3	1.43	Mg-HCO_3
2006	Marbareh	2.2	0.2	0.06	0.01	0	2	0.2	0.27	Ca-HCO_3
2012	Marbareh	2	0.8	0.05	0.01	0	2.2	0.3	0.36	Ca-HCO_3
2016	Marbareh	2	0.6	0.05	0.03	0	1.8	0.5	0.38	Ca-HCO_3
2017	Marbareh	1.5	0.8	0.05	0.01	0	1.6	0.4	0.16	Ca-HCO_3
2001	Kamandan	2.4	0.6	0.03	0.02	0	2.2	0.2	0.58	Ca-HCO_3
2006	Kamandan	2	0.5	0.04	0.01	0.2	2	0.2	0.15	Ca-HCO_3
2012	Kamandan	2.8	0.6	0.05	0.01	0	2.9	0.3	0.25	Ca-HCO_3
2016	Kamandan	1.6	0.9	0.08	0.01	0	2	0.3	0.29	Ca-HCO_3
2017	Kamandan	1	0.8	0.06	0.01	0	1.5	0.2	0.17	Mg-HCO_3
2001	Darehtakht	2.2	0.5	0.03	0.02	0	2.5	0.15	0.04	Ca-HCO_3
2006	Darehtakht	2	0.5	0.05	0.01	0.2	2	0.2	0.13	Ca-HCO_3
2012	Darehtakht	1.5	0.5	0.02	0.01	0	1.7	0.2	0.13	Ca-HCO_3
2016	Darehtakht	2.2	0.5	0.07	0.01	0	2.2	0.3	0.28	Ca-HCO_3
2017	Darehtakht	1.8	1	0.13	0.01	0	2.4	0.3	0.24	Ca-HCO_3
2001	Chamzaman	3.6	3.4	0.27	0.06	0	5.5	1.2	0.51	Mg-HCO_3
2006	Chamzaman	2	0.3	0.05	0.01	0	2	0.2	0.16	Ca-HCO_3

Table 2. Physico-chemical parameters of groundwater of Azna city

Year	Station	pH	EC	TDS	Na%	SAR	TH
2001	Marbareh	7.12	488	312	2.91	0.057	254.6
2006	Marbareh	8.21	280	176	2.83	0.055	220
2012	Marbareh	8.07	291	225	2.1	0.042	250
2016	Marbareh	7.75	270	174	2.99	0.044	220
2017	Marbareh	7.92	246	193	2.54	0.047	195
2001	Kamandan	7.44	285	179	1.64	0.025	160
2006	Kamandan	8.46	270	170	1.96	0.036	235
2012	Kamandan	7.92	352	186	1.73	0.038	315
2016	Kamandan	7.9	261	164	3.48	0.072	225
2017	Kamandan	7.97	193	119	3.74	0.063	165
2001	Darehtakht	7.3	257	162	1.82	0.026	160
2006	Darehtakht	8.51	270	170	2.34	0.045	235
2012	Darehtakht	8.04	205	131	1.48	0.02	185
2016	Darehtakht	7.87	276	170	2.88	0.06	245
2017	Darehtakht	7.86	302	155	4.76	0.11	260
2001	Chamzaman	7.35	702	456	4.5	0.144	384.61
2006	Chamzaman	8.16	280	176	2.54	0.047	215

3.1. Total Dissolved Solids (TDS):

The highest amount of TDS is in the Chamzaman river in the year of 2001 with the amount of 456 and the lowest amount of this parameter is related to the Kamandan river in year 2017 with a rate of 193 mg / L. In the Marbareh river, the maximum amount of total dissolved solids is in the year 2001 with 312 and the minimum amount is in the year of 2016 with 174 mg /l.The TDS fluctuation rate in the Daretakht river is not high, the highest amount is in years of 2006 and 2016 with 170 and the lowest amount is in the year of 2012 with 131 mg / l.Also, the rate of this chemical parameter is in the Chamzaman river in the year of 2006, is 176 mg/l and the highest amount is in the Kamandan river in the year of 2012 with 186 mg /l.

3.2. Water hardness (TH):

The lowest level of hardness is in the year of 2001 with 160 mg /l Caco3 for the rivers of Kamandan and Daretakhta. Its highest amount is 384.5 mg / l Caco3 for the Chamzaman river in the year of 2001. In the Marbareh river, the least amount of hardness is in the year of 2017 with195 mg /l Caco3 and its highest amount of this parameter is in the year of 2001 with 254.6 mg/l Caco3. The highest level of hardness is observed in the Darethakht river in the year of 2017 with 260 and in the Kamandan river in the year of 2012 with 315 mg / L Caco3. The hardness in the Chamzaman river in the year of 2006 is 215 mg / L Caco3. Marbareh river and the Kamandan river in 2017,Kamandan in the year of 2001 and the Daretakht in the year of 2001 and 2012 are in the minimume of national standard hardness. All rivers have the WHO 2011 standard. In the Schuler drinking water standard, all the specimens are excellent and the Marbareh and Chamzaman in the year 80, Kamandan in the years of 2006 and 2012, and the Daretakht in the year of 2016 have acceptable quality.

3.3. Electrical conductivity (EC)

Chamzaman in the year of the 2001 with the electric conductivity of 702, the highest and the river of Kamandan in the year of 2017 with 193 have the smallest amount of this parameter.

The Marbareh river in the year of 2001 with amount of 488 electric conductivity and in 2017 with a value of 246 mho per cm has the highest and lowest values of this parameter, respectively. EC in the river of Daretakht in the year of 2017 with 302 and in 2012, with 205 mho per cm, respectively, had the highest and lowest rates.Also, the lowest amount of EC in the Kamandan river in the year of 2017 was 193 mho per centimeter. In the Chamzaman river in the year of 2006, the EC value has been 288 mho per centimeter.

3.4. Acidity (pH):

The highest of the pH value was in the river Dareh-takht in the year of 2006, with a amount of 8.46 and the smallest amount related to the Marbareh river in the year of 2001 with a amount of 7.12.The highest amount of this chemical parameter in all rivers has been in the year 2006 with an approximate value of 8.3 and the lowest in the year 2001 with an approximate value of 7.3. For pH, all samples are in the standard range. 67.47% of the samples had good pH, 17.65% of the samples had acceptable pH and 88.8% of samples had moderate pH.

3.5. Anions (Hco_3^-, So_4^{2-}, Cl^-):

The highest amount of anion there is in the Cham-zaman river and in the year of 2001 with about 7.21 and the lowest amount of it there is in the river of Kamandan with 1.87 mg/l in year of 2017 .Marbareh river has the highest and lowest levels of anion in the year of 2001 with 5.3 and in the year of 2017 with 2.16 mg / l.The carbonate content of all years was 0 .Kamanan river in the year of 2001 with 2.98 and in 2017 with 1.87 mg / l has the highest and lowest amount of anion. Also, the amount of carbonate in the year 2006 was 0.2 mg / L, and in the rest of the years there was no carbonate in the river.

The river of Dareh-takht with the amount of anion 2.94 in year 2017 and the amount of 2.03 mg/l in 2012 year had the highest and lowest amount of anion. The amount of carbonate in the river in the year of 2006 was 0.2 mg / l and in the rest of the years it was zero. It should be noted that the amount of anion in the Cham-zaman in the year of 2006 was 2.36 mg / l, and bicarbonate is the major of the existing anion in the rivers.

3.6. Cations (Mg^{2+}, Na^{+}, K^{+}, Ca^{2+}):

The highest amount of cation is 7.3 mg / l for the Cham-zaman river in the year 2001 and its lowest amount is in the Kamandan River with1.87 mg / l in the year of 2017 .

In the Marbareh river, there is the highest and lowest cations respectively, in the year of 2001 and 2017 with a rate of 5.15 and 2.36 mg / l .The highest amount of cation in the Kamandan River is 3.46 mg / l in the year of 2012 .The river of Dareh-takht has the lowest and the highest cationic in 2017, with 2.94 and in the year 2012, with 2.03 mg / l .It should be noted that the amount of cation in the Cham-zaman river in the year of 2001 was 2.36 mg / l. The highest and lowest cation concentrations in all rivers in the studied years have been calcium and potassium, respectively.

3.7. SAR:

The highest amount of SAR relate for the Chamzaman river in the year of 2001. This amount is 0.44 mg / L. The minimum amount of this chemical parameter is 0.02 mg / l, in the Daretakht river in the year of 2012.The Marbareh River in the year of 2001 with the amont of 0.057 and in the year of 2012 with the amount of 0.042 mg / l had the highest and lowest SAR respectively. The Kamandan River in the year 2001, with 0.025 and in the year 2016 with 0.072 mg / l, had the highest and lowest values of this parameter, respectively.

Also, most of the SAR value in the river of Dareh-Takht is relate of the year 2017 with 0.11 mg / l, and amount it in Chamzaman river in the year of 2006 is 0.047 mg / l .

3.8. Na% :

The highest and lowest percentages of sodium in the Daretakht river is 4.76% in the year 2017 and 1.48 percent in the year of 2012 . This parameter in the Marbareh river in the year of 2016 with 2.99% and in the year of 2012 with 2.1% is in the highest and lowest, respectively . Sodium percentage has increased significantly in the river of Kamandan. The highest and lowest rate of Na% observed in the year of 2017, with 3.74 and the year of 2001, with 1.64 percent respectively.The Chamzaman River in the year of 2001 and the year of 2006 has been 4.5% and 54.2 percent of sodium, respectively.

3.9. Piper diagram:

Water classification was done based on important cations and anions in the Piper diagram (Fig.7). Based on this, the highest anion and cation in the rivers are Hco_3 and Ca^{2+}, respectively .The type of water is Ca-HCO_3 in all of the years studied except Marbareh and Chamzaman in the year of 2001. These rivers are in the Mg-HCO_3 type in the year 2001.

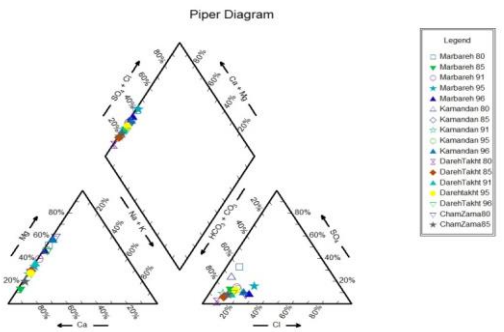

Figure 7. Piper diagram of ground water quality of Azna city

3.10. Wilcox diagram:

According to the Wilcox diagram (Fig. 8), except for the Kamandan and Marbareh rivers in the year of 2017 and the river of Daretakht in the year of 2012, all rivers fall in to the C2S2 category. Marbareh and Kamandan rivers in the year of 2017 and Daretakht in the year of 2012 are in C1S1category. Chamzaman river is located near the border of C3 in the year of 2001 and in the year of 2001 it has the highest salinity risk among the rest of rivers. In terms of sodium content, rivers are in excellent condition for all years.

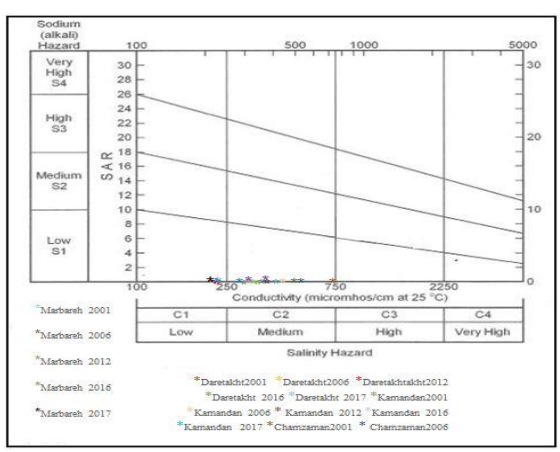

Figure 8. Water classification based on Ec and TDS values

3.11. Schoeller diagram:

According to the Schoeller diagram (Fig. 9), it Can be to determine the amount of elements of sodium, magnesium, chloride and sulfate in different rivers in different years. According to this diagram, all rivers are suitable in Schoeller's view for the quality of water, and they are of great quality for drinking, and the river of Daretakht has been acceptable in the year of 2017 on the hardness of drinking.

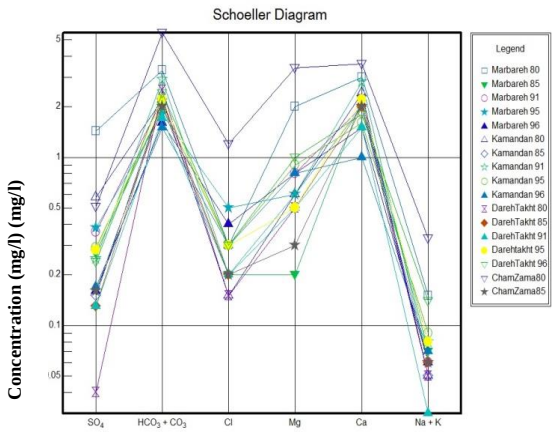

Figure 9.classification of Schoeller diagram for drinking water in Azna city

4. Conclusions

According to the diagrams, bicarbonate, and then the sulfate has the most amount In between another anions. The highest amount of cations in the rivers is calcium and then magnesium.The water type in all rivers has been Ca-HCO3 after year of 2001. Also, in the years 2012, 2016 and 2017, the amount of anion and cation in the rivers of Marbareh and Kamandan has decreased. pH in the rivers in the year of 2001 with approximate amount of 7.3 has been the lowest and in the year of 2006, this chemical parameter was the highest amount of with about 3.8. Amount of SAR increased in the Marbareh and Daretakht rivers from the years of 2012 to 2017, this increase more has been in the river of Daretakht. also this chemical parameter has been high in Kamandan river too.The percentage of sodium has also increased significantly in the rivers of the Kamandan and Daretakht from the year of 2012 to 2017.According to Schuler and Wilcox diagrams, it can be concluded that in general, the city's rivers have a good quality drinking water, and are a bit of salinity and suitable for agriculture. the river of Dharetakht in the year of 2012 and the rivers of Kamandan and Marbareh in the year of 2017, have been sweet and very good for farming. In total, the Kamandan River has the best quality among the rivers of the city. Quality in this river in year of 2017 has been better than the another of the years and for agricultural purposes the risk of salinity has been lower than in previous years.

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