Investigation of Groundwater Quality for Irrigation in Karak District

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Abstract-Groundwater is one of the important resources for irrigation in many parts of the world. The contamination of groundwater and lack of parity between groundwater extraction and recharge has posed a serious threat on its use. It is due to deteriorating groundwater quality and depleting water table. The purpose of this research is to investigate the groundwater for irrigation qualitatively and quantitatively for Karak District. Public awareness and economic prosperity of the people in this district is also aimed.

To serve this end, 24 groundwater samples were collected for determining the concentration of major ions like Sodium (Na), Potassium (K), Magnesium (Mg), Calcium (Ca), Carbonate (CO3) and Bicarbonate (HCO3). Commonly used parameters like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate(RSC), Permeability Index (PI), Magnesium Absorption Ratio (MAR) and Kelly's Ratio (KR) were determined for assessment of groundwater quality for its use in irrigation.. Secondly, the crop-water need was also calculated using software CropWat 8.0 for windows to ensure sustainable use of groundwater for irrigation. Rainfall, cropping pattern, crop intensity, soil type and humidity data was collected for this purpose.

The results of irrigation water parameters show that the groundwater is suitable and sustainable for its use in irrigation in Karak District if certain measures like creation of organizational setup and sustainable management are taken to handle the problems.

Keywords-Irrigation, parameters, Groundwater, Karak, Index, CropWat

I. INTRODUCTION

Land degradation and other environmental problems have resulted due to excessive use of groundwater [1]. Wells are going out of range owing to the fact that water level is lowered a lot that has made pumping expensive. These problems took place because the exploration of wells exceeded the management of groundwater [2]. The groundwater is deemed fit if plants and animals do not affect due to mineral constituent of the water [3]. Salts damaged plants physically and chemically. The physical damage is done by limiting growth of plants by osmotic process and chemically by the effect of hazardous substances through metabolic processes. Developing countries could not develop management of groundwater owing to numerous reasons [4]. The situation is further aggravated by secondary salinization that is tied with the use of poor quality water [5]. Soils are largely affected by salts that have characterized the ecology of Indus Basin. These problems have threatened the use of groundwater for agriculture. The lack of information is a major impediment in the way of groundwater management. Also the information relating to various variables like withdrawal quality, water availability and ground are nonexistent. Keeping the statistics of groundwater is a first step in managing the groundwater [6]. Number of tube wells their utilization facts and total groundwater pumped is listed in different estimates that exist in Pakistan [4]. The depletion of water table takes place in Khyber Pakhtunkhwa and Baluchistan. 1% of GDP needs to be spent on water resources in Pakistan to avoid worse situation. The current spending on GDP 0.25% is deplored by the World Bank.

This paper is aimed to investigate groundwater in Karak and analyze its suitability for irrigation in district Karak. This study is associated with the qualitative analysis of groundwater and quantitative analysis of water needs of crops with respect to irrigation. The chemical evaluation is aided by statistical analysis to help evaluate the groundwater chemistry. In addition to that, groundwater quality is affected by irrigation and to protect and evaluate groundwater, it is necessary to unearth the hydrochemical characteristics of groundwater. In order to evaluate the groundwater quality, 24 samples were examined and ionic concentration of Sodium, Calcium, Potassium, Magnesium, Carbonate and Bicarbonate were found. It is followed by the application of irrigation water parameters to check it for normality. The crop water requirements (CWR) were also determined to know whether amount of water required for crops is provided or insufficient supply of water is in place. Besides that, being a semi-arid, the knowledge of CWR is needed to ensure full justice with sustainable irrigation. For that purpose temperature, relative humidity, wind speed, sunshine hours and rainfall were collected from district Karak.

A. Geography of Study Area

The district Karak has an area of 2650km² and comprises of three tehsils. Tehsils Banda Daud Shah has an area of 744 km², tehsils Karak has an area of 1050km² while tehsils Takht-e-Nasrati has an area of 856km² (see Map 1) The population is estimated as 610,000 according to Khyber Pakhtunkhwa development statistics and a population density of 230 persons per km².14% comprises urban population whereas 86% is rural population [7]. Sedimentary rocks, sandstone and salt rocks characterizes Karak valley. The rock formations consists of Chinji formation that consists of reddish shale and sandstone, Nagri formation consists of predominantly "sandstone with occasional shale beds, DhokPathan formation consists of sandstone, shale and conglomerates and Soan formation consists of reddish brown shale and brown sandstone. Northern side of the Karak district has an aquifer that is characterized by saline water.

B. Climate of Research Area

Karak has a varying precipitation and temperature seasonally with semi-arid situation. Temperature rises in summer and drops in winter. Average annual precipitation is 524mm. The months of June to November gives 70% precipitation whereas 30% precipitation comes in the months of December to May. Summer rains are of high intensity with short time period whereas winter season has low intensity rains with long periods. Summer is hot with monsoon in the month of May to June while winter is too cold owing to the western wind.

II. Materials and Methods

To conclude the groundwater elementalogyin the district Karak under natural conditions, 24 groundwater samples were obtained from shallow and deep wells/tube wells in the area. The concentration of chemicalionswas analyzed in the laboratory. A statistical relation of coefficients among different ions shown in Table V. The ionic concentration of Na, K, Ca, Mg, CO_3 and HCO_3 were determined in this regard besides determining PH concentration. Fig. 2-6 shows the ion scatter diagram for groundwater sample in this regard. The irrigation water parameters were calculated using (1)-(6) after the ionic concentration is found. The values of SAR, SSP, RSC, MAR, PI and KR after calculation were compared with FAO limits. The CWR was determined using CropWat 8 for windows after feeding rainfall, sun hours, humidity, wind, soil data etc. The results for irrigation water and rainfall contribution were achieved in this regard.

III. Results and Discussion

A. Physical Parameter and Ions Chemistry of Groundwater

In current hydrochemical research, 24 samples were collected and examined for physical and different chemical parameter like Na, Ca, K, Mg, CO_3 and HCO_3. PH is the measure of acidity or alkalinity of water and hence determines its suitability for irrigation purposes. The PH value was recorded for 24 samples in district Karak to determine the suitability of water. An abnormal value of PH may cause problems to irrigation equipment's like pipe corrosion and nutritional imbalance. The values are tabulated in the Table I and the recorded PH value revealed that the PH was found within the prescribed limit of FAO except few stations where it was above the prescribed limit Table IV.

The chemical parameters were checked against the desirable limits as prescribed by FAO. The desirable limits are also indicated in the Table IV along with statistical analysis to help examine and evaluate this hydrochemical analysis. The irrigation water quality determination is dependent upon the information on groundwater chemistry. That in turn leads to the application of irrigation water parameters. The results indicated that in most of the locations, groundwater is suitable for irrigation Table II.

Hydrochemical evaluation is also supported by statistical analysis to help examine the groundwater evaluation and display information. The correlation coefficient is shown in Table 5.; a linear relationship between two variables is measured by its direction and strength. A high positive correlation coefficient was found among Mg, CO_3, HCO_3, and Ca. A high positive correlation was also found between Na and K and between Ca and CO_3. Scatter diagram shown in Fig. 1-4 shows that the scatter diagram falls below the trend line (1:1). In scatter graph, it is showed that the metals are inducing close association among each other.

B. Irrigation Water Parameters

Various groundwater qualities parameters have been used to check the suitability of Groundwater for irrigation purpose. The chemical parameters are found and then a complete examination of groundwater takes place with irrigation water parameters that judge the water quality for irrigation. Various parameters, discussed earlier like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), residual Sodium Carbonate (RSC),Magnesium absorption ratio (MAR), Permeability Index (PI) and Kelly's Ratio (KR,) were calculated to find out the suitability of groundwater. The values of Groundwater quality parameters are shown in the Table III. The classification scheme shown in the Table II shows the percentage of samples in the safe zone or suitable for irrigation as per irrigation water quality criteria. All the measurements were taken in milliequivalent per liter (meq/l). The desirable limits along with statistical analysis are also shown in the Table IV displaying the information about Groundwater evaluation.

SAR is the measurement of effect of Sodium ion concentration relative to Calcium and Magnesium ions and it indicates the negative effects of these ions on soil. When the SAR value increases, it effects the soil aeration. The SAR values of all the 24 samples were calculated work shown in Table 3 using the (1), [5].

$$SAR= \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad (1)$$

The minimum and maximum values of SAR are 0.30 and 7.37 meq/l with a mean value of 1.84 and SD (standard deviation) of 2.04. Its suitability was also checked as per categorization of Richards, 1954 and according to the categorization, excellent category ranges from a SAR value of <10meq/l, marginally suitable value ranges from 10-18meq/l, doubtful category ranges from 18-26meq/l and unsuitable category includes a SAR value greater than 26meq/l. After checking the values, it was concluded that 100% samples were of excellent category and none of the sample was labelled as marginally suitable, doubtful or unsuitable Table II. So the Groundwater was deemedfit for irrigation on the basis of SAR value.

Higher concentration of RSC induces higher PH and effects water for irrigation. An abnormal value may affect the soil fertility and higher value of RSC may induce precipitation of Magnesium that may increase Sodium concentration. The RSC values of all the 24 samples were calculated work shown in Table III using the (2), [5].

$$RSC = (CO_3+HCO_3) - (Ca+Mg) \quad (2)$$

The minimum and maximum values of RSC were found to be -5.37 and 11.00Meq/L with the mean value of 1.87 and a SD (standard deviation) of 4.65. According to Richards, 1954 [5] categorization, the water sample having RSC value less than 1.25 is considered good, doubtful category ranges from 1.25-2.5 and a water sample is considered unsuitable when the value exceeds 2.5. The results were evaluated that revealed that 58.33% samples were of good quality, 8.33% were of doubtful category and 33.33% were of unsuitable category. Most of the samples were deemed fit for irrigation while few were deemed unfit for irrigation especially in MithaKhel where RSC value was highest and found as 11.00meq/l where in Dagarnari, Surdag, Shanawa Gudi Khel, Amberi kali, main Bogara and Latember, the calculated SAR values were 9.8, 5.77, 6.66, 9.56, 9.01 and 5.10Meq/L respectively and the values were too high making it unsafe for irrigation. On the whole, the water was found fit for irrigation with maximum samples 58.33% found good and 8.33% samples were doubtful Table II.

Magnesium absorption ratio is an important parameter for measuring water quality for irrigation. When Magnesium content becomes high in water, it becomes toxic for irrigation. Here in the study area, Magnesium absorption value was calculated shown in Table III for all 24 samples, using the (3), [8].

$$MAR = Mg \times 100 / (Ca + Mg) \quad (3)$$

The minimum and maximum value was calculated as 4.74 and 68.76 % respectively with a mean value of 29.71 and a standard deviation of 15.77 Table IV. Ayers [8] shows that the samples exceeding 50% are unsuitable for irrigation and less than 50% makes it suitable for irrigation. The calculated values indicated that 91.67% samples were found below 50% so these were fit for irrigation while 8.33% samples were exceeding 50% so those were unfit for irrigation due to higher Magnesium ratio Table IV. Most of the samples were fit for irrigation and few showed slight increase in Magnesium.

Sodium hazard is measured by Soluble Sodium Percentage (SSP) by measuring Sodium accumulation that may cause harm to irrigation process. Soil structure disorder, aeration and infiltration may take place. SSP is calculated to measure these hazards and depict picture Groundwater chemistry. SSP was measured for all 24 samples shown in Table III using the 4, [4].

$$\%Na = \frac{(Na+K)x100}{(Ca+Mg+Na+K)} \quad (4)$$

The minimum and maximum values were calculated as 8.64 and 85.89% respectively with a mean of 47.33 and a standard deviation 22.18. According to Wilcox, 1955, excellent category ranges from 0-20%, good category ranges from 20-40%, permissible category ranges from 40-60%, doubtful category ranges from 60-80% and more than 80% makes an unsuitable category. After calculating the values, it was established that 16.66% samples comprised excellent category, 25% samples comprised good category, 29.16% samples comprised permissible category, 16.66% samples comprised doubtful category and only 12.5% samples comprised unsuitable category Table II. Few samples showed higher SSP including Zebi, MohabatKhel and Ahmad Abad where SSP exceeded 80% mark and hence comprised unsuitable category. On the whole most of the samples were deemed fit for irrigation.

Soil permeability is affected by consistent use of Irrigation water and to measure this, PI was calculated in all 24 samples of study area shown in Table III using the (5).

The content of Calcium, Magnesium, Sodium and Bicarbonate in soil besides the use of Irrigation water for longer periods, effects soil permeability. Long term use of irrigated water contributes towards the effecting of soil permeability. Resultantly soil type, HCO3 (Sodium Bicarbonate) and TDS (total dissolved solids) are the constituents that are affected (Gabriel and Sheriff, 2011). PI more than 75% belongs to class I (suitable) category while PI in a range of 25-75% belongs to class II (unsuitable) category. The following (5) was used to determine PI.

$$PI = (Na + HCO3) x100 / (Ca + Mg+Na) \quad (5)$$

The minimum and maximum value was calculated as 32.55 and 99.07 % respectively with a mean value of 67.29 and a standard deviation of 22.18 Table IV.

The class II samples are deemed unfit for Irrigation while class I are deemed fit for Irrigation. . When PI value is greater than 75%, it is suitable for Irrigation and secondly when the value is in the range of 25-75%, it is unsuitable so according to this classification 50% of samples are deemed fit for Irrigation and the remaining 50% were in the range of 25-75% so deemed unsuitable.

Kelly's Ratio is another parameter to measure and gauge the Groundwater quality suitability for Irrigation purposes. The value of less than 1 belongs to safe (suitable) category while KR greater than 1 belongs to unsafe (unsuitable) category. So it is used to judge the water quality for Irrigation. It is calculated using the following (6).

$$KR =Na/ (Ca + Mg) \quad (6)$$

The minimum and maximum value was calculated as 0.07 and 4.21Meq/L respectively with a mean value of 0.8025 and a standard deviation of 1.14. According to Kelly, 1963, when the value of water sample is less than 1, it is suitable for Irrigation and when the value exceeds 1, it is unsuitable for Irrigation. According to this classification, 83.33% samples are fit for Irrigation and the remaining 16.66% samples were unfit for Irrigation.

C. Water Quantity for Irrigation

The study was conducted to check the physibility of water quantity for irrigation purpose in our research area. Crop Water Need (CWR or ET_c)is the amount of water required to reimburse the loss of water through evapotranspiration. It may also be stated that the crops requires water for growth and to provide crops with optimum water, is crop water need (FAO, 1986). The elements that crops water requirement (CWR) depends upon are the climate (cloudy climate requires less water than hot climate), the crops type (there is a difference of crop water need for each crop) and growth stage of the crop (mature crops need more water) [10]. Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount [11]. By calculating the soil water balance of the root zone on a daily basis, the timing and the depth of future irrigations can be planned [5].

The results for all crops were calculated by the software. The data was collected from Agriculture Research CenterKarak where rainfall, humidity, wind speed, sun hours and others are measured. An average total of 543.09mm annual rain is measured in the last 10 years in the area with an average humidity of 57% and average minimum temperature of 15.8°C and average maximum temperature of 28.7°C. The average wind speed was 84km/day and sun hours were measured as 12.3 hours a day.

The reference evapotranspiration (ET_o) was calculated as 4.35mm/day on the average. Resultantly, the Crop Water Requirement was calculated like the CWR of wheat comes out to be 325.4 mm in the season. The crop water need met by effective rain is 128.1mm whereas shortage of 196.1mm is met from Groundwater. Likewise, the results of seasonal crop water need for all crops are listed in the Table VI that shows the Crop Water Requirement. When the shortfall is met from the groundwater, it causes a continuous water table drop and it has constantly taken place in the area with many wells dried after use. This situation requires sustainable groundwater management which is to maintain a balance between extraction and recharge. The statistical evaluation is shown in Table VII that shows a mean value of 391.21.

By utilizing CropWat software for Windows 8, we figured out the crop water demand. The reference evapotranspiration can be determined by simply entered the climate data. Later on the soil, crop and monthly rainfall data was entered and resultantly, ETC and irrigation required was computed directly by the software. The Crop Water Requirement can be calculated on daily basis but in this study it is calculated on 10 days period basis. The results calculated showed the amount of water required for crops besides the water provided by rainfall and received from irrigation. Hence the groundwater in district Karak has to fulfill the vacuum created by rainfall. It is an opportunity for farmers of the locality to preserve the already depleting water resources by knowing the CWR.

The Crop Water Requirement of 8 crops namely wheat, barley, gram, rape and mustard, Jawar, Bajra, maize and groundnut was determined as the results are tabulated in the Table VI. The results show the total crop water need and that required from irrigation.

IV. CONCLUSIONS

Our research reveal that the groundwater of district Karak generally claimed to be fit for irrigation however the abnormal values of RSC, SSP and PI at some stations reduce the suitability of groundwater for Irrigation but to sum up all these, it is concluded that the water was found suitable for Irrigation in the study area. Secondly the rainfall contribution to the Crop Water Requirement has compelled Groundwater to meet the required deficiency and it is depleting Groundwater resources drastically. It is recommended to preserve the Groundwater by efficient use of water for Irrigation.

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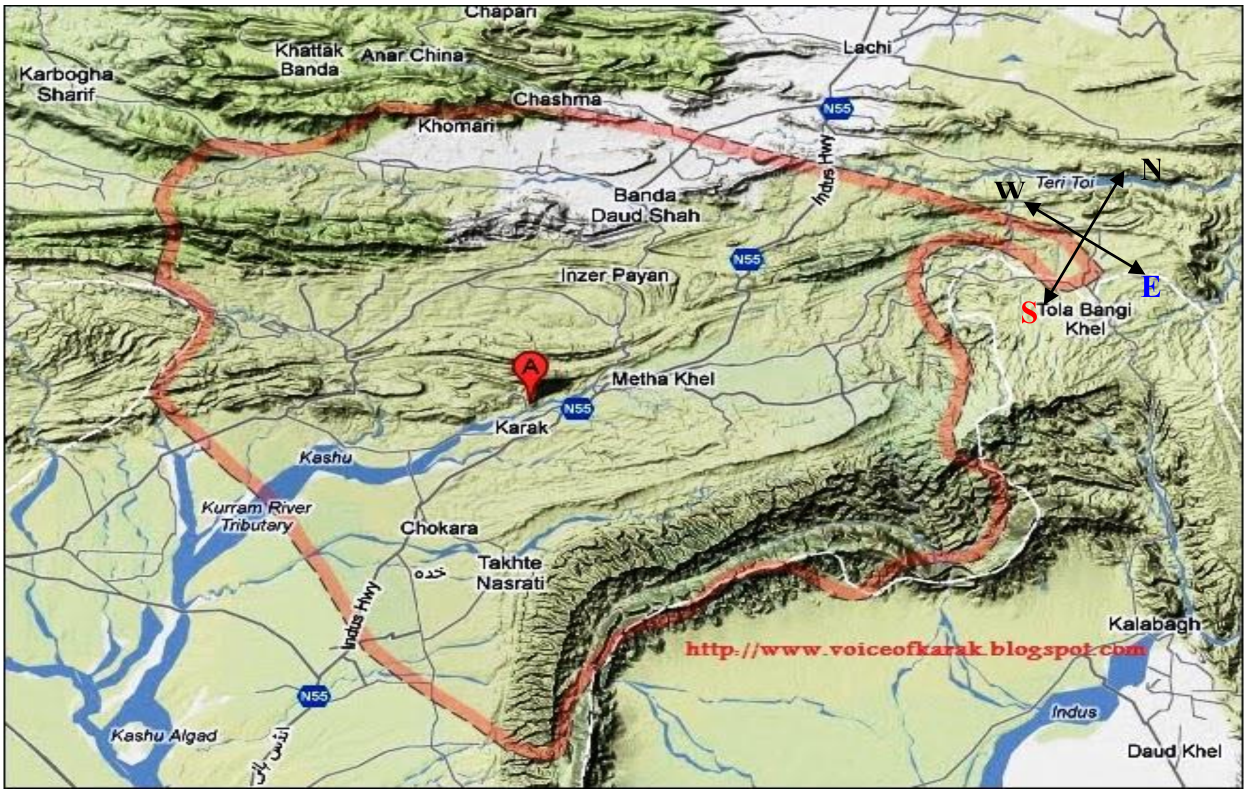

Fig.1. Map of Study Area

TABLE I
PH CONCENTRATION IN GROUNDWATERSAMPLES

Sr. #	Code	Location	Temp ^{0}C	PH
1	IC	Isek Chontra	25.1	8.3
2	PS	Palosa Sar	27.3	8.1
3	KK	Kandu Khel	29.2	7.9
4	SA	Sabir Abad	28.1	7.9
5	MK	Mitha Khel	30.1	9.0
6	TK	Talab Khel	23.5	7.9
7	GMK	Ghundi Mirhan Khel	25.3	8.0
8	K	Karak	27.6	8.3
9	KM	Kamangar	29.5	8.3
10	TD	Thordand	28.7	7.9
11	Z	Zabi	27.9	8.1
12	L	Latember	24.8	8.3
13	S	Surdag	25.9	8.3
14	DN	Dagar Nari	28.6	8.4
15	AK	Amberi Kale	29.2	8.5
16	SGK	Shanawa Gudi Khel	28.9	8.3
17	ZK	Zarkai	27.7	8.2
18	MB	Main Bogara	28.7	8.1
19	AA	Ahmad Abad	29.5	8.6
20	MK	Mohabat Khel	29.4	8.2
21	SS	Shah Saleem	27.8	8.4
22	GK	Ghondi Kala	27.4	8.0
23	SK	Shadi Khel	25.3	8.3
24	T	Topi	27.1	8.5

TABLE II
CLASSIFICATION SCHEME

Classification scheme	Categories	Ranges	Percent of Samples
SAR(Richards 1954)	Excellent/suitable	<10	100%
	Marginally Suitable	10-18	0%
	Doubtful	18-26	0%
	Unsuitable	>26	0%
RSC(Richards 1954)	Good	<1.25	58.33%
	Doubtful	1.25-2.5	8.33%
	Unsuitable	>2.5	33.33%
MAR(Ayers and Westcot, 1985)	Suitable	0-50	91.67%
	Unsuitable	>50	8.33%
%Na(Wilcox,1955)	Excellent	0-20	16.66%
	Good	20-40	25%
	Permissible	40-60	29.16%
	Doubtful	60-80	16.66%
	Unsuitable	>80	12.52%
PI(Ragunath, 1987)	Class2(unsuitable)	25-75	50%
	Class1(suitable)	>75	50%
KR(Kelly,1963)	Suitable	<1	83.33%
	Unsuitable	>1	16.66%

TABLE III
IRRIGATION WATER PARAMETERS & IONIC CONCENTRATION

Sr. #	Code	Location	Na	K	Ca	Mg	CO_3	HCO_3	SAR	SSP	RSC	PI	MAR	KR
1	IC	IsekChontra	0.869	1.64	2.80	0.80	0.37	1.33	0.64	41.13	-1.94	45.34	22.22	0.241
2	PS	PalosaSar	0.62	0.85	1.65	0.95	0.45	1.10	0.54	35.96	-1.05	51.82	36.53	0.23
3	KK	KanduKhel	0.91	0.33	4.56	0.91	0.65	2.85	0.55	18.47	-1.97	40.59	16.63	0.167
4	SA	Sabir Abad	0.41	0.21	3.20	0.50	0.45	1.55	0.30	14.35	-1.7	40.26	13.51	0.11
5	MK	MithaKhel	0.61	1.21	5.90	2.10	0.75	18.25	0.30	18.53	11.00	56.70	26.25	0.07
6	TK	TalabKhel	1.23	1.45	2.47	1.54	0.50	4.50	0.86	40.05	0.99	63.95	38.40	0.306
7	GMK	Ghundi Mirhan Khel	1.47	1.01	8.13	1.15	0.60	8.96	0.68	21.08	0.28	41.51	12.4	0.15
8	K	Karak	1.13	0.04	10.45	1.92	3.92	10.66	0.45	8.64	2.21	32.55	15.52	0.10
9	KM	Kamangar	7.45	3.21	15.3	3.21	5.53	7.61	2.44	36.54	-5.37	39.32	17.34	0.40
10	TD	Thordand	3.56	4.92	11.65	2.41	3.29	5.67	1.34	37.62	-5.10	33.71	17.14	0.25
11	Z	Zabi	6.29	3.89	1.34	0.81	2.31	3.00	6.06	82.52	3.16	95.04	37.67	2.92
12	L	Latember	2.14	4.56	1.14	2.51	2.41	6.34	1.58	64.73	5.10	80.44	68.76	0.58
13	S	Surdag	2.39	6.74	2.09	0.91	3.56	5.21	1.95	75.2	5.77	86.68	30.33	0.79
14	DN	DagarNari	1.75	3.46	2.19	1.72	4.50	9.21	1.25	57.12	9.80	84.53	43.98	0.44
15	AK	Amberi Kale	1.50	2.36	1.62	2.15	3.12	10.21	1.09	50.50	9.56	89.09	57.03	0.39
16	SGK	Shanawa Gudi Khel	2.01	3.81	1.99	0.89	1.50	8.04	1.675	66.89	6.66	99.07	30.9	0.69
17	ZK	Zarkai	1.45	0.14	3.01	0.15	1.13	4.01	1.15	33.54	1.98	75.00	4.74	0.45
18	MB	Main Bogara	1.14	3.43	2.01	1.84	2.17	10.76	0.82	54.27	9.01	88.58	47.79	0.29
19	AA	Ahmad Abad	7.37	4.81	1.57	0.43	0.21	0.93	7.37	85.89	-0.86	88.94	21.5	3.68
20	MK	MohabatKhel	5.78	2.13	0.97	0.40	0.19	0.77	6.96	85.23	-0.41	93.11	29.2	4.21
21	SS	Shah Saleem	3.17	3.29	1.13	0.81	0.14	0.99	3.23	76.98	-0.81	81.48	41.75	1.63
22	GK	Ghondi Kala	1.75	0.92	2.00	1.50	1.11	1.37	1.32	43.27	-1.02	55.62	42.8	0.5
23	SK	ShadiKhel	1.00	0.04	2.10	0.22	0.10	2.05	0.93	30.95	-0.17	73.27	9.48	0.43
24	T	Topi	0.55	1.33	0.99	0.45	0.33	1.02	0.65	56.62	-0.09	78.38	31.25	0.38

TABLE IV
SUMMARY STATISTICS OF ALL PARAMETERS

Parameter	Unit	Minimum	Maximum	Mean	SD	Desirable limits	Remarks
PH	-	7.9	9.0	8.23	0.23	6.5-8.4(FAO)	83.33% fit
Na	Mg/L	.43	171.35	54.193	49.642	0-900(FAO)	100% fit
K	Mg/L	1.564	263.53	90.879	72.618	0-78(FAO)	54.16% fit
Ca	Mg/L	19.40	306.00	75.217	76.236	0-400(FAO)	100% fit
Mg	Mg/L	1.83	39.162	15.392	9.97	0-60(FAO)	100% fit
CO_3	Mg/L	3.00	165.90	49.113	47.671	0-30(FAO)	50% fit
HCO_3	Mg/L	46.97	113.3	336.49	273.97	0-600(FAO)	83.13% fit
SAR	Meq/L	0.30	7.37	1.84	2.04	<18	100% samples are suitable
SSP	%	8.64	85.89	47.73	23.39	0-60	70.82% samples are Suitable
RSC	Meq/L	-5.37	11.00	1.87	4.65	<1.5	58.33% samples are of good category
PI	%	32.55	99.07	67.29	22.18	>75	50% samples are suitable
MAR	%	4.74	68.76	29.71	15.77	0-50	91.76% samples are suitable
KR	Meq/L	0.07	4.21	0.8025	1.14	<1	83.33% samples are suitable

TABLE V
CORRELATION COEFFICIENTS AMONG DIFFERENT IONS

	Na	K	Ca	Mg	CO_3	HCO_3
Na	1.000					
K	0.5278	1.000				
Ca	0.2208	-0.0519	1.000			
Mg	0.1138	0.2683	0.6050	1.000		
CO_3	0.2699	0.4401	0.5400	0.7169	1.000	
HCO_3	-0.1987	0.0676	0.3932	0.6328	0.4728	1.000

TABLE VI
CORP WATER REQUIREMENTS

Crops	Location	ETC(mm)	Effective rain(mm)	Irrigation required(mm)
Barley	Karak	202.7	99.9	103.2
Wheat	Karak	325.4	128.1	196.1
Gram	Karak	311.4	129.9	183.8
Rape & Mustard	Karak	288.9	128.4	159.6
Maize	Karak	359.1	202.8	204.6
Jawar	Karak	520.8	287.5	235.7
Bajra	Karak	470.4	252.7	267.2
Groundnut	Karak	651.0	330.1	322.6

TABLE VII
STATISTICAL EVALUATION OF CWR

Statistical evaluation of CWR	
N	8
Mean	391.21
SD	145.55
SE Mean	51.459
Minimum	202.70
Maximum	651.00

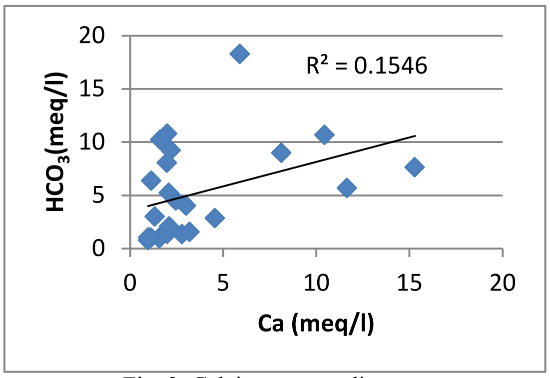

Fig. 2. Calcium scatter diagram

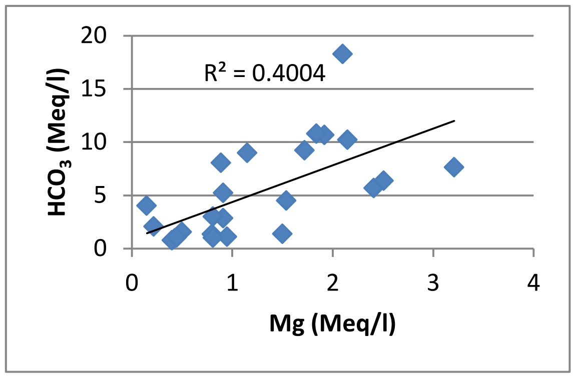

Fig. 3. Magnesium scatter diagram

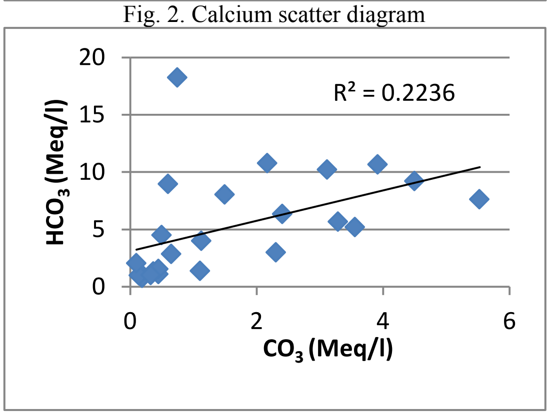

Fig. 4. Carbonate scatter diagram

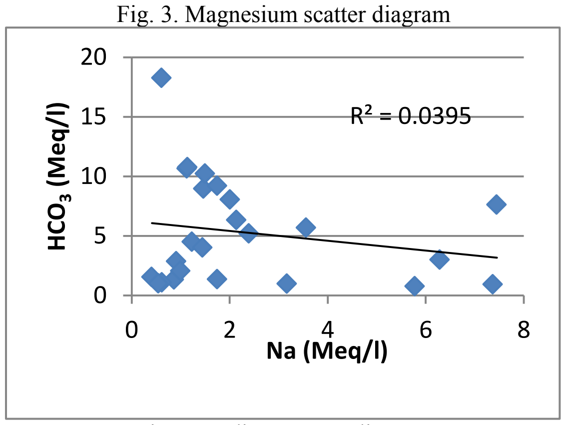

Fig. 5. Sodium scatter diagram

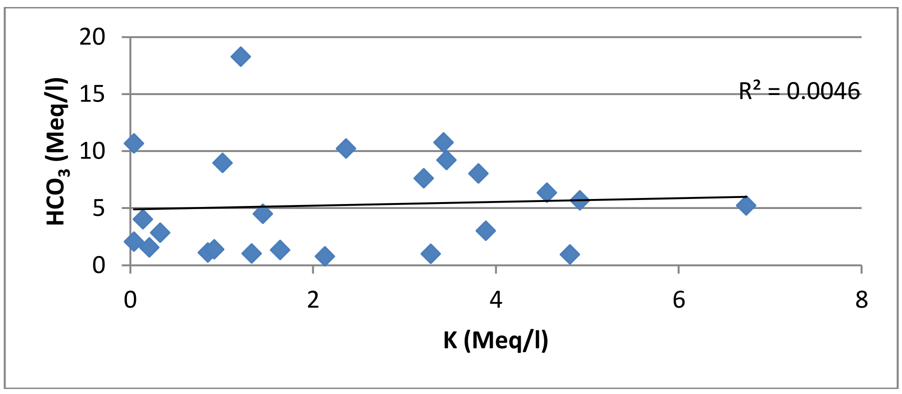

Fig. 6. Potassium scatter diagram

Fig. (2)-(6) shows Ion scatter diagram for groundwater sample in the study area (trend line shows average between ions